THE TECHNIQUE OF SCREEN PRINTING

C. Sugumar

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Illustrations by the Author

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Preface

There is hardly a person today who is not familiar with the term ‘screen printing’. Almost everyone seems to be aware that it is a printing process used to put lettering and pictures on paper and other surfaces. Many also seem to recognize that this technique is rather different from the mainstream printing processes such as letterpress, lithography and gravure conducted on regular presses. Other than this, the average person seems to possess hardly any knowledge about the subject of screen printing. Indeed, even a modern 1,800-page dictionary published by a famous university press describes screen printing as *“a method of printing by forcing ink through a pattern cut into a piece of cloth stretched across a frame”.* This is a fine dictionary and an admirable compilation, but the brief definition of screen printing offered here is completely off the mark. This example is provided just to illustrate how people can get even the most basic assumptions wrong when attempting to delve into the mysteries of this fascinating subject. When one endeavors to explore this field in increasingly greater depth, the scope for making more such erroneous assumptions keeps expanding further.

This is most unfortunate because screen printing is an interesting and widely practiced process that accounts for a substantial proportion of the printing industry’s worldwide output. Sometimes it is the best technique for printing on certain types of substrates and on many awkwardly shaped surfaces.

The long list of equipment, processes, materials and chemicals that are the stock in trade of this industry can prove confusing and daunting to the beginner who may feel lost if he attempts to do any screen printing without undergoing a period of formal apprenticeship or enrolling in some training course first. The objective of this book is to enable the rank beginner to embark on a screen-printing career by putting to use the knowledge acquired by perusing it and by depending on his own wits. It is entirely practicable to become a capable screen printer by learning from this book alone and following the detailed instructions given in it. The beginner can thereafter practice it as a hobby, craft or business that can generate a good and steady income.

Detailed information is provided about the equipment, materials and processes employed in modern screen printing. Descriptions of the older stencil making techniques such as those based on glue, shellac and tusche are also given to provide some idea as to how this process evolved. Some diehard hobbyists and artists may still employ such materials to obtain certain special effects, but the contemporary screen printer will prefer to use superior products that have been developed in recent years. These are far easier to use, as they give better and more consistent results.

Comprehensive information is given about the various operations and procedures involved in the pre-production and production stages of screen printing, which should help the beginner to put them into practice with confidence. Great care has been taken to ensure that all operations are explained in detail because the author realizes how distressing it can be for the beginner to find that crucial information has been omitted. The book starts at a basic level, assuming no prior knowledge of this field by the reader. He is introduced to the various aspects of the subject in easy stages and in clear language that anyone can understand. The subject matter is built up progressively and in the later chapters some advanced information is presented that even practicing screen printers would find useful. This information will be of relevance if they are planning to diversify their activities to include related but more specialized work.

The basic principles and standard procedures of screen printing are explained in the first ten chapters. This is necessary to acquire a good understanding of the procedures

described in detail in the following six chapters. Crucial operations such as emulsion coating and drying, preparation of positives, exposure of stencils and mounting of photo stencil films are discussed in detail in these chapters. Two of these chapters are devoted to a detailed explanation of the role played by computers, printers and graphics software in the production of positives needed for exposing stencils. The next chapter is devoted to procedures involved in reclaiming the screen so that it can be used again. Actual production techniques are described in detail in the next six chapters for printing on a wide variety of substrates with diverse properties. The last chapter offers general advice on the subject, encompassing all aspects of screen printing. An earnest attempt has been made to present all this information in as logical and orderly a sequence as possible. However, it is not entirely practicable to do so, and it often becomes necessary to touch briefly on certain matters in the earlier chapters while reserving a fuller explanation of same for later chapters. This is why a second reading of the book would considerably enhance the reader's comprehension of the information presented.

Printing of books is carried out sometimes with letterpress or more usually by lithographic processes and not by screen printing. For most other types of printing though, this technique is immensely popular, especially for non-paper-based substrates. A screen-printing shop can have a broad customer base due to the wide variety of substrates that can be printed using this process. Even though the basic principles are the same, it requires a specialized approach to screen print on each type of substrate, as they all call for special types of inks, stencils, and techniques. The inexperienced printer would be at a loss when confronted by a material he is not accustomed to working with. An important objective of this book has been to provide specific guidance to the novice printer to find the correct method for working with every type of printing surface.

Information on screen printing is scattered widely in books, magazines, journals, websites, manufacturers' instructions and data sheets but it is just about impossible to find all the pertinent facts in one place. This book attempts to fulfill that need by presenting in a concise manner all the information that would assist the newcomer to enter the field of screen printing and learn the trade painlessly and speedily. At the same time, the history of screen printing, detailed descriptions of obsolete processes and other superfluous information have been left out. It is hoped that this book will enable the reader to get onto the fast-track straightaway as the various topics have been presented in a manner that is easy to understand and assimilate.

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Acknowledgements

The information presented within the pages of this book was gathered from hundreds of different sources and includes a few things that I learnt during my own career as a screen printer. While it is not feasible to give credit to every source, I must acknowledge that much helpful information was acquired from the product data sheets and other technical publications issued by the following companies that are the leading suppliers of screen-printing materials and supplies, worldwide. They are *Autotype Ltd, Ulano Ltd, Chromaline Screen Print Products,* and *Sericol Ltd.*

I prepared all the drawings in the book. As I was unable to do any freehand drawing, I had to rely on the computer to generate the drawings. Here too, I did not make use of illustration software for this purpose as is customary but resorted to the use of drafting software. Despite having no previous experience as an illustrator, I was able to achieve better results than I had hoped for, due to the capabilities of the *Autocad* drafting and modeling software. *Photoshop* was used to a limited extent for touching up some of the drawings after converting them to the bitmap format.

I must express my gratitude to my wife and sons who were patient with me when I was engrossed in writing this book while neglecting some of my domestic responsibilities.

Chapter 1 – Basic Principles

One of the earliest methods developed by man for printing text and images serially was screen printing. Its origin may be traced back to early Egyptian and Chinese civilizations. It remains the most versatile printing process of all due to its adaptability that enables printing to be performed on soft or hard materials, absorbent or impermeable substrates and flat or cylindrical surfaces. It is possible to print on a wide range of materials such as metal, wood, glass, ceramics, plastics, rubber, fabrics and of course paper and cardboard. A vast range of inks and coatings are available for deposition on substrates by the screen-printing process. These materials are carefully formulated to meet the specific requirements of each application as closely as possible.

Screen printing gives a durable image with strong, bright colors because the amount of ink deposited is far greater than in any other print process. The ink coverage can be dense enough that light colored inks may be used to print on dark backgrounds. It is possible to vary the thickness of the ink deposit within wide limits to get the desired result. The process lends itself admirably to work involving special effects inks such as metallic, glitter, fluorescent and phosphorescent types. Flock material may be applied by dusting onto freshly inked surfaces while the ink is still wet and tacky. Raised effects with rounded profiles are easily achieved and profiles with sharply defined edges are possible with special inks and techniques. Etch resist coatings may also be applied accurately and conveniently by means of the screen-printing process.

The term ‘Serigraphy’ is applied to the limited production of art prints using screens whereas ‘screen printing’ refers to normal industrial operations involving this technique. Artists employ mostly manual methods to produce unique artworks in serigraphy while the commercial screen printer resorts to mass production techniques to increase his output.

The *Mimeograph* that was very popular in the first half of the last century for producing multiple copies of documents was based on the use of a special type of stencil. This stencil material was made of a wax-based composition that resembled paper, but unlike paper was quite brittle. It was kept intact by a thin net-like skeleton of fibrous material that served as reinforcement. When the stencil was kept on a hard surface and written or drawn on with a small round tipped stylus, the stencil material directly under the tip disintegrated and created tiny open areas that followed the path traced by the stylus. The network of filaments embedded in the original structure of the stencil remained unaffected and continued to hold the remaining portions of the stencil securely in place. A typewriter could also be used to create a stencil with the standard characters by shifting the ribbon out of the way. The impact of the type head could equally well create the necessary impression on the stencil material, opening it up where desired.

To make reproductions of the lettering or hand drawn art on the stencil, it was kept flat on the paper that was to receive the impression and an inked rubber roller passed across its surface. The ink passing through the tiny openings in the stencil created the impression on the paper underneath. The operation could be repeated to produce multiple copies. The stencil was later attached to a round drum to mechanize the process and speed up production. The *Mimeograph* process is defunct now.

In screen printing, ink is deposited on a surface by being forced through a rectangular piece of open weave fabric stretched tightly over a rigid frame. Some parts of the fabric are sealed to block the passage of ink while other parts carrying a likeness of the matter to be printed remain open and allow the ink to pass through to be deposited onto the surface below. A printing screen is essentially the same as a stencil made of sheet material such as that used to apply markings on cardboard boxes and wooden crates.

These stencils are usually made of stiff cardboard cut to the required form. Stencils could also be made of sheet metal, stiff rubber or thin sheet plastic. Simple shapes such as letters and numbers of a bold size may be marked out by using stencils of this type, but they are not suitable for producing fine detail or elaborate work. An unacceptable feature of these stencils is that ‘bridges’ or more correctly, ‘ties’ must be provided to locate and hold in position the numerous ‘islands’, that is, unsupported areas usually present in any printed output as shown in the illustration.

Notice how the ‘bridges’ or ‘ties’ break up the design badly, disrupting the continuity of the matter to be printed. For these reasons, stencils cut out of sheet material prove unsuitable for most commercial printing work and their utility is restricted to the labeling and addressing of packages and shipping crates.

Fig 1.1a Marking stencil cut out of sheet material

Fig 1.1b Lettering printed out by marking stencil

A simple screen-printing stencil may be constructed by stretching a strong, non-absorbent fabric material with an open weave such as organdy tightly over a rectangular wooden frame and fastening it securely by driving in nails around the periphery. Numbers or lettering are drawn or traced onto a sheet of thin, strong paper the same size as the screen frame. The design is cut with a sharp, pointed knife along the traced lines. The pieces of paper corresponding to the areas to be printed are removed carefully and discarded but the ‘islands’ in the middle of the letters that drop off must be retained. Gum is applied lightly onto the upper surface of the large piece of paper and the screen frame is pressed down firmly onto it. The screen is flipped over and the smaller pieces of paper that comprise the ‘islands’ in the lettering are lightly coated with gum, positioned carefully in the correct locations and stuck firmly onto the organdy mesh. Surplus gum should not ooze out from under the paper as it will block the openings in the surrounding areas and produce untidy prints.

When the gum has dried fully the resulting screen may be used with most non-water-based inks to print the lettering on any even surface. Compared to stencils cut out of sheet material, the great advantage of using a mesh-based stencil, referred to as a screen, is that there will be no sign of any ‘bridges’ to disfigure the lettering or the design.
In fact, mesh stencils do have ‘bridges’ in the form of numerous slender yarns that support the ‘islands’ but since they possess a very fine structure, the ink can flow around

them smoothly without giving rise to any discontinuities. Using a stencil formed on mesh, it is a simple matter to print neatly a pattern made up of nested ‘islands’ as shown in the drawing below without any hint of the unsightly ties. According to an expert, “the essential function of a screen-printing stencil is to direct the flow of ink to image areas and to block the flow of ink to non-image areas in a precise and controlled manner.”

Specialists involved in the screen-printing trade have identified more than three or four dozen distinctly different ways of making stencils (depending on how one chooses to do the classification). In this book however, we will focus only on the practical, contemporary, and commercially viable processes that use materials and techniques readily accessible to everyone.

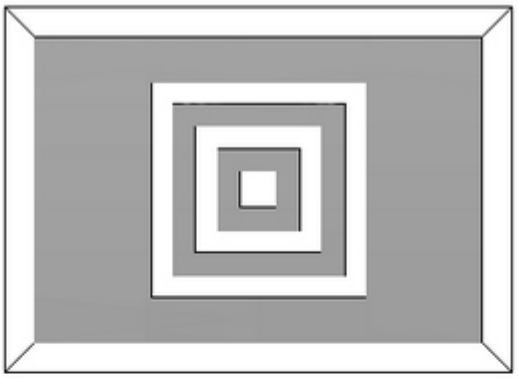

Fig 1.2a Stencil for printing a pattern of nested squares

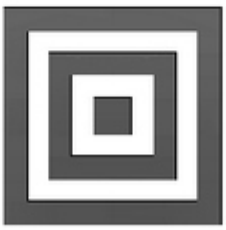

Fig 1.2b Pattern of squares printed on paper

A basic screen-printing setup comprises a smooth, hard and flat surface on which the material to be printed is placed. A screen such as the above is attached to one side of this baseboard by a simple mechanism that allows the screen to swing up and down in an arc. This mechanism is a combination of hinge and clamp. One end of the screen frame is secured to the clamp so that it may pivot on the hinge as its outer end is raised and lowered. This makes it easy to feed in blank material and remove the printed material in succession while at the same time ensuring the ink pattern is always deposited at the identical location. The printing of paper may be considered as a simple example. The screen frame is raised up and the paper to be printed is placed in the correct position that is marked on the baseboard. The screen frame is swung down, and a quantity of printing ink is placed on the mesh inside the trough of the frame. All screen-printing inks have a paste-like consistency. The ink is spread lightly all over the stencil area by means of a squeegee, which has a thick rectangular blade made of rubbery material fixed securely to a handle. The squeegee is an important tool used by the screen printer. Squeegees are discussed in detail in *Chapter 6*.

To start printing, the squeegee is placed at the hinged end of the screen, pressed down firmly onto the stencil to force it into contact with the paper and pulled steadily towards the operator. The squeegee, as it moves down the screen, pushes a puddle of ink in front of it while at the same time forcing a controlled quantity through the open areas of the stencil onto the surface of the paper below. The screen frame may be raised now and the sheet of paper that has received the print removed carefully, as the ink would still be wet. Careful examination will show that the inked areas on the paper correspond to the open areas on the stencil and the blank areas on the paper match the blocked areas as shown in the drawing.

The schematic drawing below shows how the ink is distributed onto the substrate in a selective manner by the combined action of the stencil and squeegee.

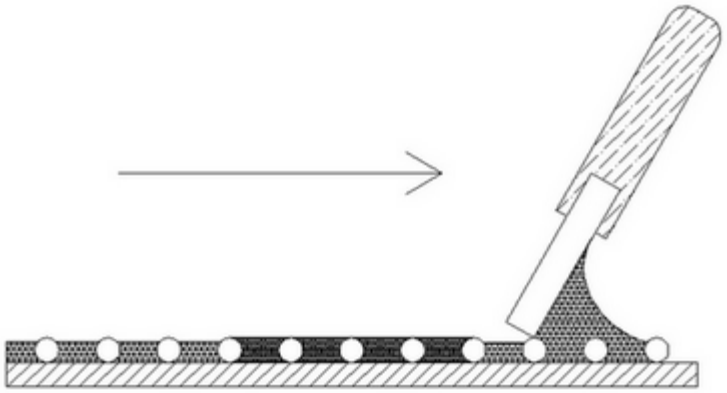

Fig. 1.3 Blocked areas (dark gray) prevent ink (light gray) from reaching the substrate below.

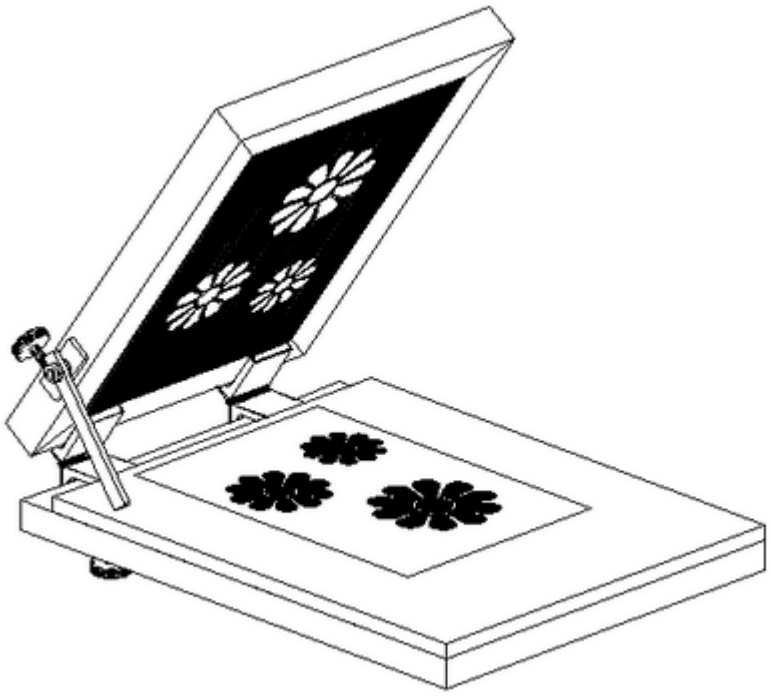

Fig. 1.4 The wiping action of the squeegee forces ink through the open areas of the stencil, depositing a thin layer of it on the paper placed beneath.

The foregoing is a brief description of the screen-printing process. Detailed explanations are given in later chapters. There is one important point though, that should be grasped at the very outset. When the screen frame is lowered onto the substrate, the underside of the stencil does not actually rest on the surface to be printed because it is necessary to provide a small clearance between the two for the process to work effectively; that is, to prevent the smudging of ink. The lower surface of the stencil makes only simple line contact with the substrate where the edge of the squeegee presses down on it and that too only momentarily because the stencil springs up as the squeegee passes on. This gap between the stencil and the surface to be printed is known as the 'snap' or 'off-contact' and is dependent on such factors as the size of the screen and the tension in the mesh. In the absence of a gap between the two surfaces, the printing ink will not be transferred through the openings in the mesh onto the substrate cleanly and efficiently. Omission of this feature will also cause the ink to be pushed under the lower surface of the screen onto the regions bordering the open areas, resulting in smudged prints. This will become quite evident during long production runs. The drawing below illustrates the principle of 'off-contact' or 'snap'.

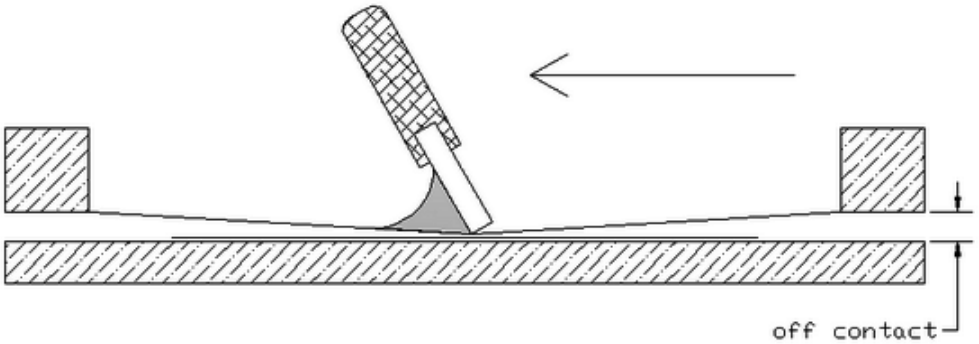

Fig. 1.5 'Snap' or 'Off contact' is an essential feature of screen printing as it promotes sharper output by enabling better control over ink transfer.

A rudimentary mesh type stencil may be made by stretching and tightening organdy fabric onto a large embroidery hoop and trimming off the surplus. A circular sheet of paper with a small, simple design cut in the middle portion is pasted with gum to cover the entire lower surface of the mesh. A thick, rectangular piece of rubber with a straight edge is used as the squeegee. Solvent-based inks must be chosen because water-based inks will dissolve the gum. A hair dryer may prove useful to dry the gum on the stencil and the ink on the print rapidly. Stencils such as these have been used for printing numbers and letters neatly onto various surfaces when a limited number of prints, such as for athletic events, had to be made at very short notice with homemade equipment!

Chapter 2 – Mesh Fabrics

Fine silk material with an open weave served as the mesh during the early days of screen printing and the technique was described as silk screening. Use of the term ‘silk screen’ and its derivatives is frowned upon by the modern practitioner of this art. Now the process is referred to simply as screen printing because the use of silk cloth has been superseded by other woven materials such as nylon, polyester and even stainless steel mesh as they are more capable of withstanding the rigors and demands of modern production methods. The special grade of silk favored by the early screen printer was a fine, strong fabric called bolting cloth, woven from natural multi-filament fiber on handlooms and originally used for screening flour!

Currently, polyester monofilament yarn is firmly established as the material of choice for making screen printing mesh. Polyester yarn is very strong, possesses great chemical stability and is optically clear. It is also physically stable, being highly resistant to the action of the numerous solvents used in printing inks and screen washes. Its moisture absorption is very low, which is a desirable trait as any deficiency in this attribute can lead to a change in dimension and loss of strength as screens constantly get wet. Strength and inertness always prove to be of great value, but the clarity could turn out to be an advantage or disadvantage depending on the exposure requirements when preparing photo stencils. Polyester mesh made of multi-filament yarns is also available for very heavy-duty work. When printing on smooth, hard, and flat surfaces such as thick plastic sheets, metal, glass and hardwood, the best results are obtained with polyester monofilament mesh. For carrying out multi-color printing with tight registration too, this is the ideal material. Screen printing mesh is made of nylon too and this material is more suitable for printing on soft materials like fabrics and on uneven surfaces such as those on plastic bottles. Nylon is more elastic than polyester and this slight extensibility enables it to conform more closely to uneven surfaces promoting an even deposit of ink. Nylon is more prone to absorbing moisture than polyester though and this can lead to some loss of strength and tension when used with water-based inks.

A characteristic of polyester mesh that is highly valued by the more experienced screen printer is its propensity for work hardening. Such a mesh is stronger and more stable and therefore able to deliver very consistent results during long production runs. Advantage is taken of work hardened mesh by stripping off any old stencil on it that has served its purpose and putting on a new one. The mechanism of work hardening is based on a more parallel alignment of the long chain molecules being brought about by the constant stroking action of the squeegee blade. If the squeegee direction is reversed at any time, the orientation of the molecules would be disturbed by being forced to re-align in the opposite direction, diminishing the strength and hardness of the yarns. Therefore, the direction of the printing stroke should be marked permanently on the screen frame and the orientation of any new stencil put on the mesh, matched to this.

Mesh is available in a fine or coarse form and this property is defined accurately by a number known as the mesh count, which refers to the number of openings per linear inch of the screen material. This may range from a very coarse 32 openings per inch to a very fine 360 openings per inch. The most used mesh counts are 48, 54, 62, 80, 100, 120, 140,170, 200, 240 and 270 openings per inch. The actual numbers and the intervals between them vary somewhat by manufacturer. The mesh count along the warp threads (which run the entire length of the bolt) and along the weft threads (which run transversely from the left edge to the right edge) is usually the same so a 50-count mesh would have 2500 openings per square inch and a 200-count mesh would have 40,000 openings per square inch! However, it is not unusual for mesh to have unequal mesh counts in the two directions, in which case the openings would be rectangular. Mesh counts are sometimes

specified in terms of centimeters. To convert openings per inch to openings per centimeter divide by 2.5 and to perform the reverse conversion multiply by 2.5. There is a quaint mesh numbering system in which the designated count must be multiplied by a factor of ten to arrive at the actual mesh count. No doubt, the British would have devised this system!

Fabrics with low mesh counts are coarse but strong and useful for depositing thick coatings of ink on the surface to be printed; however, they cannot reproduce fine details faithfully. Fabrics with high mesh counts have a fine structure but the materials are delicate and must be treated with care. They can reproduce finely detailed matter accurately by laying down a thin but uniform layer of ink. Although fine mesh fabrics are useful for printing high resolution images they tend to clog up with ink while the work is in progress. Certain types of ink are more prone to blocking the tiny openings than the rest.

Screen fabrics with identical mesh counts may have been woven with yarns of different diameters. The fabric woven with the thinner yarn would be thinner but would have larger openings and the fabric woven with the thicker yarn would be thicker but with somewhat smaller openings as shown in the accompanying diagram. The yarn diameter is measured in microns, a micron being equal to one millionth of a meter.

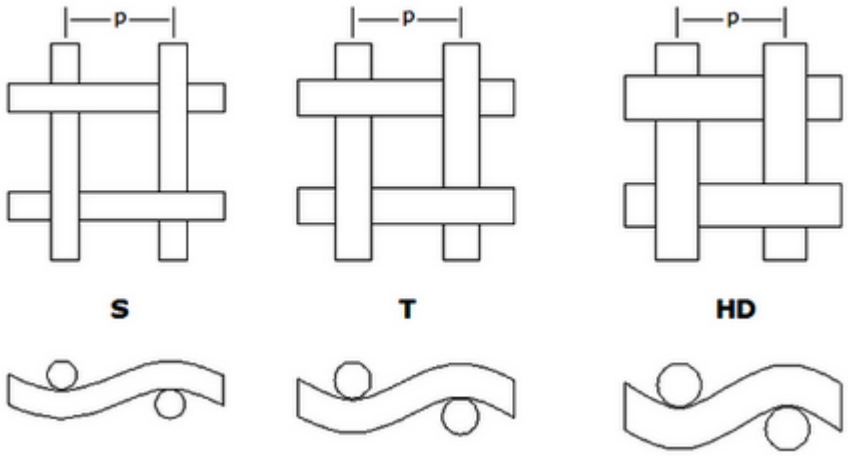

Fig. 2.1 Fabrics with the same mesh count can use yarns of different thicknesses but the pitch ‘p’ between them would be the same.

Interestingly, mesh with smaller openings is more likely to deposit a thicker coat of ink than mesh of the same count with larger openings because the amount of ink deposited is dependent more on the thickness of the mesh than the size of the openings! The mesh count of yarn is usually printed on the selvedge (reinforced border) of the fabric. The thickness of the yarn is indicated by a suffix appended to this. The letter ‘S’ indicates a small yarn size, the letter ‘T’ indicates a traditional, that is normal yarn size and ‘HD’ represents heavy duty yarn. Additional information such as the type of weave may also be marked on the edge of the fabric with PW indicating plain weave and TW, twill weave. The latter type is often found in high mesh count fabrics as it makes close weaving easier. Multi-filament yarn will often carry the mark ‘xx’ to facilitate easy identification.

For most normal work, mesh woven with standard ‘T’ type yarn would serve admirably. The smaller ‘S’ type mesh is used when rather thin deposits of ink are desired. This mesh cannot be tensioned highly due to its lower strength. Mesh made from ‘HD’ type yarn may

be used for heavy duty work with highly tensioned screens and for very long print runs. This type of screen can deposit a heavier coating of ink on the surface to be printed but of course, there are other ways of controlling the thickness of the ink deposit.

Mesh fabric is also available in yellow and orange colors. The purpose of dyed mesh is to eliminate fuzziness and undercutting caused by refraction and reflection which cause much scattering of light by the transparent material of the yarn. The use of dyed mesh can result in the production of sharper stencils with better definition. They do require longer exposure times though, roughly 50 to 100% longer than for clear white mesh. Calendared mesh is another example of the wide variety of meshes available to the modern screen printer. Calendared mesh is produced from regular mesh by flattening the raised areas on the weave pattern with a heated roller to render a more level profile. Usually, one side is flattened, and the material is known as semi-calendared mesh. This type of processing slightly reduces the open area of the mesh surface. The advantage conferred by semi-calendared mesh is that it enables very thin and uniform coatings to be laid down as required for certain classes of work, such as those involving the use of UV inks. To realize the benefit of semi-calendared mesh it should be affixed correctly on the screen. The more level surface should face upwards, that is, towards the squeegee side.

When choosing mesh for printing halftones, multiply the line count of the dots by 3 to determine the mesh count. For a 60 lines per inch halftone, a mesh count of about 180 would be just right. In case fabric with the exact mesh count is not available, material with the next highest count may be picked for the job. Halftones are discussed in greater detail in later chapters.

A very special type of mesh that is reserved for the most exacting work is made of stainless steel. It is woven out of fine SS strands. It is used for printing with ceramic and glass inks. It is also used in the production of intricate printed circuit boards for electronic devices. The track width and spacing between tracks on a medium tech PCB could be as narrow as 0.5mm and this level of detail could be achieved only with an accurate stencil formed on a very highly tensioned, precision woven mesh. Stainless steel mesh meets these requirements due to its exceptional strength and dimensional stability but must be mounted on a metal frame, as a wooden frame cannot withstand this level of stress. To produce printed circuit boards of uncomplicated design and generous dimensioning, fine mesh polyester fabric should prove quite adequate. Due to the opacity of the metal strands, stencils on stainless steel mesh must be exposed for at least twice as long as stencils supported on clear mesh. Great care must be taken to avoid denting the mesh on SS screens as it may prove impossible to correct this problem.

Nylon organdy is a cheap material that could prove very useful to those wishing to try their hands at screen making. It is the ideal material for experimenting and serves admirably for short print runs such as for advertising banners etc. A print run of 100 is easily achieved with an organdy screen. The material cannot be stretched too tightly on the frame as it is not even half as strong as polyester mesh but is suitable for low detail work of bold design. Very low-cost printing screens could be turned out by applying homemade photo stencil emulsions on organdy mesh fixed onto cheap wooden frames. This is explained in detail in Chapter 11.

Mesh fabric makes an excellent sieve material for screening and grading gritty matter and powders. It can also be used for screening out impurities. The material can filter insoluble clumps and other particulate matter from viscous and mobile liquids. It can also trap the larger particles of dust from air circulation systems but will clog up fast unless arranged to present a large surface area.

Chapter 3 – Screen Frames

When assembling the equipment for a screen-printing project, the screen frame will constitute the first building block. Its function is to retain securely the screen mesh carrying the stencil in a stretched and tensioned state. Frames are usually of rectangular shape and should be about 30% greater in internal width and internal length than the dimensions of the artwork or matter to be printed. These allowances are not excessive, as they have margins on all four sides. The traditional material for making screen frames is wood and a suitable variety of timber is used according to availability, which will vary regionally. Well-seasoned, structural grade wood, free of knots, serves the purpose best. The cross section should ideally be square. For smaller frames, 35 x 35mm square wood pieces should prove adequate and 50 x 50mm size is the standard for the larger size frames.

As the mesh, woven from strong yarns is stretched to a high state of tension and attached to the frame, each side member is subjected to a considerable bending force acting along its full length, which if not resisted firmly would cause it to progressively bow inwards. The screen frame must therefore be of robust construction to deal with these stresses, which could also warp it over time so that it will not sit squarely, but rock diagonally when placed on a flat surface.

There are many complicated carpentry joints but for screen frames simple joints such as the corner lap joint, corner bridle joint, or the mortise & tenon joint will serve adequately.

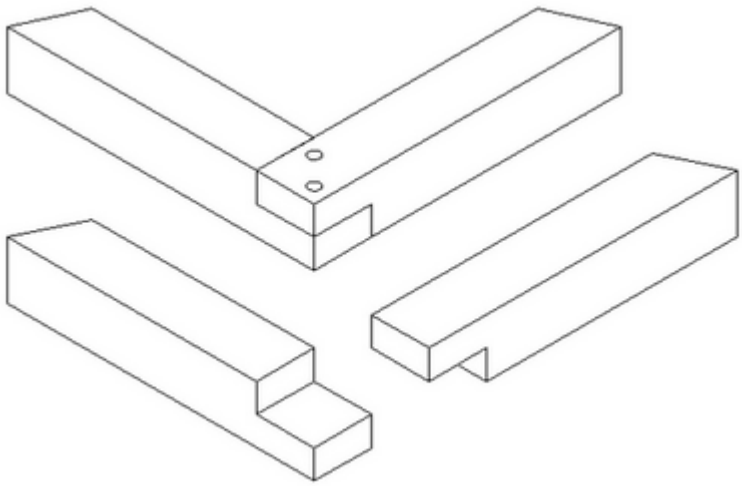

Fig. 3.1 Assembled and exploded views of corner half lap joint.

The mating surfaces should be formed accurately, and assembled carefully to ensure that the adjoining sides meet perfectly at right angles. Glue or polyvinyl acetate (PVA) adhesive, available under various brand names, is applied to the mating surfaces and fastened using two slender woodscrews at each corner. The screw heads must be slightly recessed.

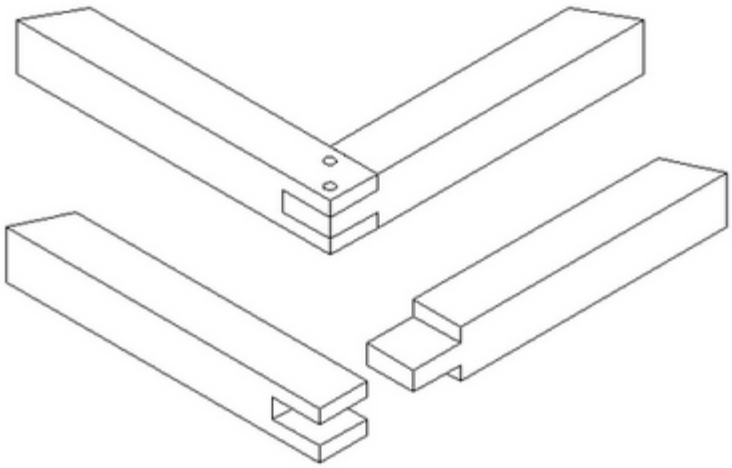

Fig. 3.2 Assembled and exploded views of corner bridle joint.

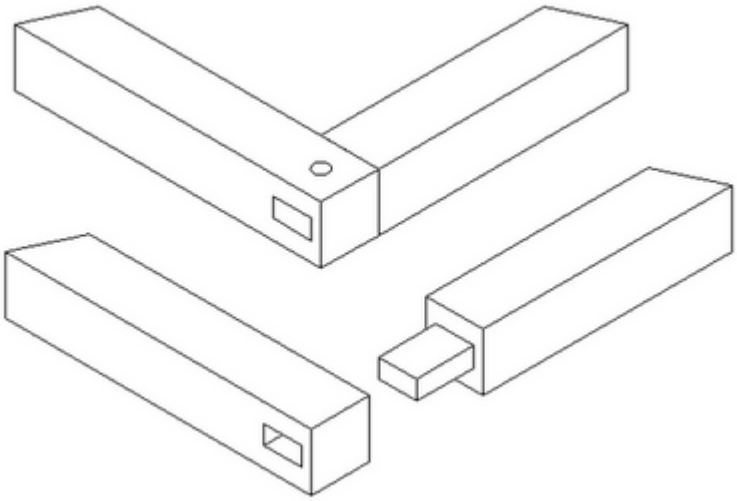

Fig. 3.3 Assembled and exploded views of mortise & tenon joint.

Polyvinyl acetate adhesive is a viscous white liquid that dries to form a hard, strong, clear film when exposed to air. Both wood glue and PVA adhesive may be rendered waterproof by the addition of a small quantity of ammonium or potassium dichromate solution that is mixed well before application. The concoction is light sensitive and cannot be stored for long even in dark bottles. When the joints have set, further work will be necessary to ensure that at least one side of the frame sits squarely on a hard, flat, smooth surface without rocking. Leveling with a plane and sanding should correct any uneven contact. All sharp edges and corners should be smoothed down by sanding to give the frame a good finish.

Wooden frames are easy to construct and inexpensive but subject to certain shortcomings such as a tendency to warp due to the absorption of moisture. This cannot be avoided entirely as all screen-printing frames come into contact with water regularly. Atmospheric humidity by itself is sufficient to cause warping of wooden frames that are

subjected to constant mechanical stresses at the same time. If this happens, the frame will distort and rock slightly when kept on a flat and level surface. The sides of the frame would also bow inwards gradually, resulting in a loss of mesh tension, which is recognized as a major cause of printing problems.

Due to the disadvantages associated with wooden frames, metal frames came to be adopted gradually by screen printers for the more demanding work. Though iron frames are used occasionally, their weight and tendency to rust have militated against their widespread adoption. Aluminium has now become the most favored material for this purpose so that extruded tubes of rectangular or square sections, which are available in an assortment of sizes and wall thickness, are used to construct frames. Long tubes of suitable cross section are cut to the necessary lengths with their ends mitered and the four outer edges slightly beveled. The cut lengths are positioned at right angles to each other, clamped in a fixture and welded with aluminium welding rods. To keep distortion to a minimum the clamps are released and frame removed from the fixture only after all the welded joints have cooled down to room temperature. The welding runs on both faces of the screen frame should be leveled and smoothed out with a hand grinder and sanding disc. Metal frames must be constructed with great care and precision as any distortion or misalignment cannot be corrected later. An aluminium frame is shown in the illustration below.

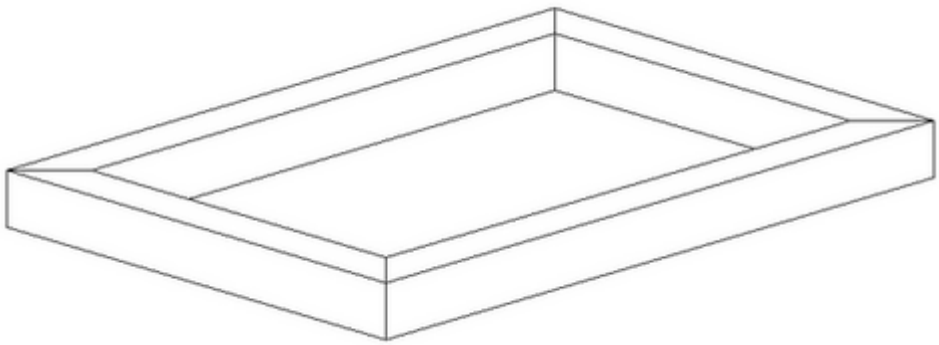

Fig. 3.4 A welded aluminium screen frame of hollow, square cross section.

The most popular method of mounting mesh on frame is by means of powerful adhesives. As aluminium extrusions do not present the ideal surface for this purpose the joint face of the frame must be subjected to some kind of treatment to promote adhesion. This is usually accomplished by a fine roughening operation that involves sanding down with a smooth emery paper one side of the frame. This will increase the surface area available for adhesion while also permitting the adhesive to key into the tiny surface irregularities. The products of abrasion should be cleaned off thoroughly from the contact surface by wiping off with a rag soaked in denatured alcohol. The contact face of wooden frames should also be lightly sanded with smooth abrasive paper and wiped clean with a rag. All surfaces should be protected from contamination after treatment, even by fingerprints, until application of the frame adhesive.

Wood and aluminium frames made by specialist manufacturers are available commercially in the most commonly used sizes without or with the mesh already fixed in place. A good quality aluminium frame would typically be constructed of 1½ inch square profile tube with a wall thickness of 2 mm and feature welded corners and sandblasted finish on one face to promote mesh adhesion. Much time can be saved by purchasing readymade screens, as there are suppliers who stock a wide assortment of sizes with a selection of popular mesh counts in each size. Some will also accept orders for custom-

made screens of the required size and with mesh counts specified by the customer. Elaborate mesh tensioning apparatus comprising numerous pneumatic cylinders and clamps arranged along the four sides are employed by specialist firms in conjunction with mesh tension measuring gauges to ensure the production of uniformly and highly tensioned screens capable of yielding accurate printed output. Remember that in the long run, aluminium frames will prove to be more economical than wooden frames because they last longer and retain their shape better.

There are re-tensionable frames, which allow the user to adjust mesh tension after it has been fixed in place. The cross section of the aluminium frame member is rather more complicated, with the mesh being locked into it by means of rubber rods wedged into deep grooves or channels running lengthwise. Two different designs of re-tensionable frame are available, one of which is known as the roller type and the other the drawbar type. With either type of frame, the mesh must be wedged in with great care to ensure even initial tension over its entire area before full tension is applied. These frames are only available from specialist manufacturers and are quite expensive.

Highly tensioned new mesh tends to become elongated after mounting and this loss of tension increases when subjected to the rigors of constant use. The mesh eventually becomes inextensible and stable by work hardening and would render excellent service if it could be restored to its original tension once again. This is the great advantage possessed by the re-tensionable frame as it can be adjusted to increase tension in the mesh even after it has been fixed in place and the stencil formed on it.

Chapter 4 – Stretching and Fixing Mesh

The traditional method of mounting mesh on a wooden frame is by tensioning the mesh by hand, section by section and nailing it to the four outward facing sides of the frame following a prescribed sequence. The procedure is to first lay the mesh fabric on a smooth, flat table covered with newspaper and then place the frame over it.

The orientation of the frame with respect to the mesh must be taken into consideration and this is usually governed by the need to keep material wastage to a minimum because screen printing polyester mesh, being a precision woven material, is quite costly. According to experts, the frame should be oriented in such a manner that its longer axis is parallel to the warp threads that run longitudinally. The rationale for this is that the warp yarns, having fewer kinks in them would have a lower tendency to stretch out and lose tension after constant use than the wavy weft yarns that run transversely. The straighter warp yarns are thus better adapted to withstand the constant movement of the squeegee blade that is normally in a direction parallel to the long axis of the frame. This will ensure better registration and a longer service life for the stencil.

The material is marked out with crayon or tailor's chalk leaving an adequate margin of mesh on each side for grasping, pulling, folding and nailing onto the frame. The mesh could be anchored to the wooden frame with ¾ inch regular wire nails or ¾ inch heavy duty staples using a stapler. ¾ inch wide strips of cloth tape should always be interposed between the mesh and the nail heads or staples to prevent any damage to the yarns. As it is difficult to tension mesh by pulling it with bare hands a special device known as a hand puller or mesh pliers is used for this purpose. This resembles a pair of regular pliers, but the working end has wide serrated jaws for gripping the mesh securely without damaging it. The device, shown in the drawing, can be purchased from screen-printing supply houses.

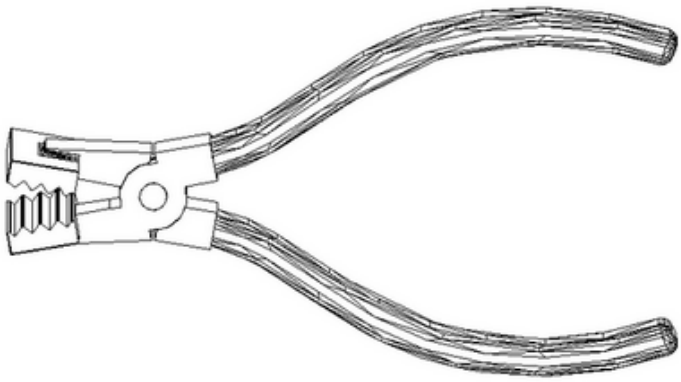

Fig. 4.1 Hand puller with serrated jaws for gripping mesh
(The width of the jaws is not apparent in this view
although they are 2 to 2½" wide).

Fixing mesh onto a wooden frame is an activity that calls for four hands so you should have an assistant to help you. Start by nailing the mesh with the protective cloth tape over it at the center of one of the longer sides of the frame. Then stretch the fabric and nail it to the center of the frame on the opposite side. Now fix one free side of the mesh to the center of one of the shorter sides of the frame by nailing. This must be executed in a balanced manner so that when the other side of the mesh is pulled and fixed to the center

of the opposite side, the yarns at the center are parallel to the wooden bars on either side. Take extra care when beginning the work as any misalignment has a tendency to keep increasing as the work progresses. Ensure that each set of yarns is always oriented parallel to the bars of the frame to its left and right.

The mesh pliers are used to grasp and tension the mesh, which is then nailed to the frame by working in a systematic manner. Conduct the operation by driving in opposed pairs of nails in pairs, alternating between the longer side and the shorter side and by working outwards from the center. The nails should be spaced about ¾ inch apart as wider spacing will lead to uneven tension in the mesh. If staples are used to affix the mesh, the stapler should be held at an angle to the side of the frame to avoid piercing the same yarn at two places. A single length of cloth tape is used on each side to protect the mesh from the nail heads or staples.

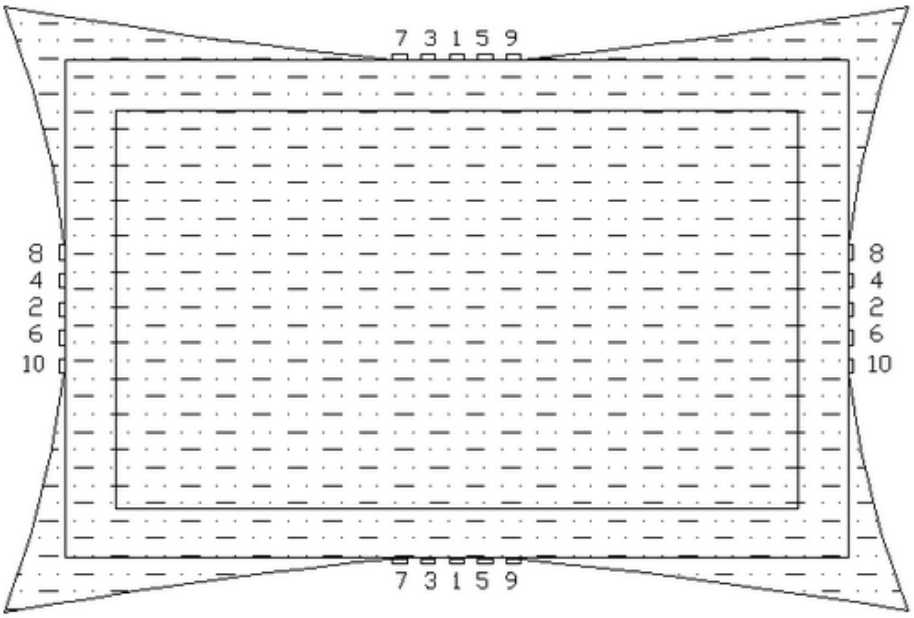

Fig. 4.2 The mesh is attached to the wooden frame with nails or staples starting from the middle of each side and in an alternating sequence.

The sequence in which the nails are driven in is indicated in the drawing above. As a greater number of nails must be used on the longer sides of the frame, it may be necessary to deviate somewhat from the sequence depicted in the drawing to ensure that the rows of nails along the adjacent sides approach the corners at about the same time. As the work progresses check constantly to ensure the yarns remain parallel to the sides of the frame. At the four corners the mesh must be doubled up neatly and folded onto the longer side and nailed in securely. When all the nails or staples have been driven in, trim off the surplus material neatly with a pair of scissors, leaving a margin of about ¾ inch extending beyond the nails or staples. The mounting of the mesh on the frame is a crucial operation that has much bearing on the quality of the stencils and the prints made from them. Therefore, execute the work with great care and deliberation, as this is not a simple and straightforward mechanical operation, although it may appear to be so. The drawing below shows a wooden frame with the mesh attached to it.

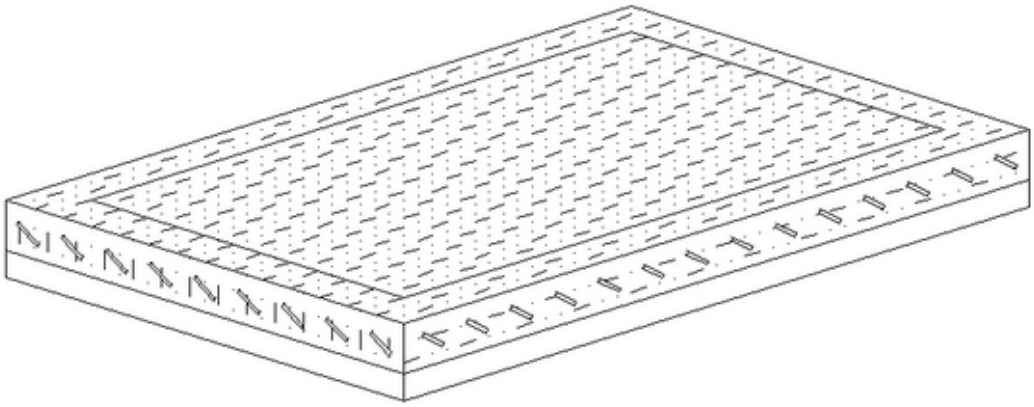

Fig. 4.3 A wooden frame with the tightly stretched mesh stapled in place.

Some practitioners of this art prefer to fix the mesh onto the frame by starting at one of the corners and proceeding in different ways and sequences to complete the operation. That approach is unlikely to yield satisfactory results and is therefore not recommended. Hand stretching is no longer in vogue but the method is described here purely because I think every screen printer should be aware of this traditional art even if he is not going to practice it.

There are two other popular approaches to stretching and fixing mesh and they are the mechanical stretching method and the pneumatic stretching method. Pneumatic stretching is based on numerous air-operated pistons, terminating in clamps, and arrayed along the four sides of the mesh. The pneumatic cylinders are mounted at close intervals on a large table or frame and have toggle clamps attached to their rams. They lock the mesh and stretch it to the required tension by means of air pressure, which is adjusted by the operator. The pressure is monitored on a gauge and is controlled with reference to the reading on a tension meter that rests on the taut surface of the mesh being stretched. Mesh tension can be set very accurately by using a tension meter, which is graduated in units known as Newtons per centimeter, abbreviated as N/cm. The tension prescribed for the normal run of work is around 25~30 N/cm and it would be wise to stick within these limits. For manually stretched screens, the tension may be as low as 5~10 N/cm, which is far below the desirable level. For very demanding work and special applications, the mesh tension may go up as high as 40 N/cm. With mesh tensions greater than 40 N/cm stainless steel or special low elongation polyester mesh must be specified.

The unit of measurement used for expressing the tension in the mesh should not be difficult to grasp. If a tensile force of 10 Newtons acts on a strip of mesh one centimeter wide, then a force of 20 Newtons will act on a two-centimeter-wide strip of mesh and a force of 50 newtons act across a width of five centimeters along the entire length of the yarns. The size of the screen is not considered because what really matters is the tension per unit width of mesh when measured along the direction of the yarns. The tension should be equal in both directions, along the screen and across it. The tension meter senses the deflection of the mesh caused by a spring-loaded probe and gives a reading on the dial. Readings should be taken with the rectangular base of the meter placed parallel to the warp yarns at several locations when applying tension. The meter should then be rotated a quarter turn and placed parallel to the weft threads to ensure equal tension in this direction too. The tension should be raised gradually by alternating between the two directions. Tension meters are expensive precision devices and as such should be handled with care. They are invaluable because they provide accurate

information about a crucial parameter, which exerts a lot of influence on the performance and service life of the printing screen.

Whereas an elaborate mesh tensioning apparatus may employ a multitude of expensive pneumatic tensioning cylinders, a simpler system may be equipped with less costly mechanical racking devices. Whether simple or sophisticated, many individual tensioning devices must be arrayed on all four sides of the mesh and mounted on a large table or metal framework. The number of these units could add up to anywhere from say, 14 to 24 for the commonly used sizes of screen frame. In addition to the heavy investment, considerable floor space would also be taken up by the entire setup. It is therefore advisable for the newcomer and small-scale screen printer to purchase frames with pre-attached mesh from specialist suppliers who have the necessary equipment and expertise to fabricate them to exacting standards and in quantity. You can get a head start by buying readymade screens as you can commence production sooner and obtain better results too.

However, there will always be many people who, for various reasons insist on doing everything themselves. They may do so in the hope of saving money or because they belong to the 'do it yourself' brigade that enjoys activities like this. For their benefit, a method of mechanically stretching and fixing mesh to frame that is simpler than the standard procedure and requiring minimal equipment, investment and floor space is given here. The method was devised by the author and yields results far superior to the manual stretching method.

This apparatus is constructed as follows: Four lengths of 2" x 2" angle iron are cut to the desired lengths to form the rectangular frame of the screen stretching device. ¼" holes spaced 6" apart are drilled along one side of each length. The ends of the angle iron are cut to 45°, beveled slightly on all edges and welded together at the corners to form a rectangular frame with the horizontal flanges facing outward. Care is taken to ensure that the adjacent sides of the frame are exactly at right angles to one another, and the welded corners ground level and finished neatly. Four lengths of wood are positioned inside the iron frame along each side as depicted in the drawing. It is important to choose some soft grade of wood for this purpose. The wooden pieces have a cross section of 2" x 1" and rest on the narrower sides so that they are the same height as the iron frame. Each length of wood is clamped to the angle iron frame on its side and holes drilled through it by passing the drill bit through the pre-drilled holes in the frame. This way the holes in each wooden piece would be perfectly aligned with the holes in the iron frame.

4" x ¼" G.I. bolts are passed through the holes in the wood pieces and the corresponding holes in the iron frame. Wing nuts are fitted to the ends of the G.I. bolts projecting outwards through the latter. Turning the set of wing nuts on each side causes the wooden bar on that side to move closer to the angle iron frame. It is necessary to have a separate angle iron frame with matching wooden bars to suit each size of screen frame in use. If you use three different sizes of frames in your shop and wish to put mesh on them, then it will be necessary to construct three of these stretching devices. The cost of three such devices, however, would still be considerably less than the cost of any apparatus making use of pneumatic cylinders or mechanical racking arrangements and the former will take up less space as well. The angle iron pieces may be orientated in an 'L' or inverted 'L' position but in either case, the horizontal flanges should face outwards. If they are in the inverted position, as depicted in the illustrations, it is much easier to lift and move the frame around, as called for by the procedure.

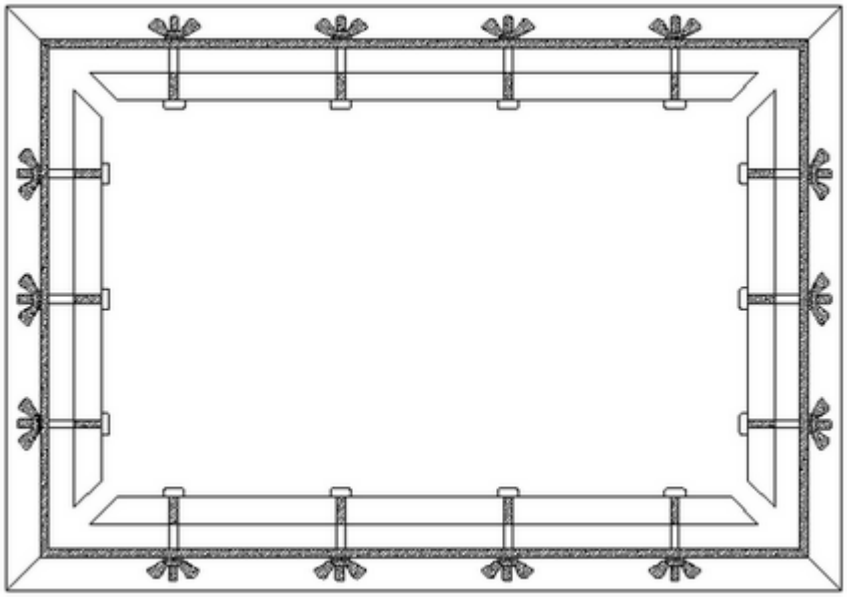

Fig. 4.4 Plan view of the mesh stretching device (Sections hidden from view are shaded).

The idea here is to fasten the edges of the mesh fabric to the four wooden drawbars with strong water-soluble adhesive and once it sets hard, tension the mesh by tightening the wing nuts progressively. This action would move the opposing drawbars away from each other by pulling each one of them closer to its side of the iron frame. To accomplish the whole task painlessly the initial setup must be carried out properly and the work executed as described. Take eight wooden spacers of one-inch thickness, measuring about 2” x 3” and insert two of them on each side in the space between the drawbar and the frame. Wedge them in position by tightening the wing nuts. The purpose of these spacers is to keep the drawbars at the correct starting position and hold them immovably when the mesh is being affixed. Using only one spacer per side could well cause the drawbar to bend somewhat when the wing nuts are tightened and that is why it is better to use a pair. The heights of all wooden drawbars should be exactly equal, and their upper and lower surfaces must be parallel. So tap and level them as best you can just before tightening the wing nuts fully.

Cut mesh fabric to a size a little larger than the dimensions of the area covered by the four wooden drawbars. Place one border of the mesh on a wooden drawbar and fasten it onto it with small nails spaced an inch apart along its length. If you have used soft wood as advised earlier, the nailing can be accomplished more easily. It is important to ensure that one set of yarns on the mesh is aligned parallel to the edge of the bar when securing it. Drive in the nails halfway and not fully, as they simply serve to hold the mesh fabric temporarily in place to facilitate subsequent operations. Now secure the opposite border of the fabric lightly with nails in the same manner to the wooden bar on that side while ensuring that the yarns running in a perpendicular direction are parallel to the other pair of drawbars. The remaining two borders of the mesh are secured with nails spaced an inch apart to the other pair of drawbars, taking sufficient care to keep one set of yarns parallel to their edges. Use just enough tension to eliminate all slack in the mesh fabric and keep it flat without applying any significant tension. Press each edge of the mesh down with the fingers onto its wooden bar and smooth it down so that both are in close contact along their full length.

Apply a coat of undiluted PVA adhesive onto the upper surfaces of the drawbars through the mesh with a ¾" paintbrush. The regular, water-soluble type is employed for this purpose, not the waterproof grade, as it should be removable. It is advisable to apply a second coat after 3 or 4 hours to ensure a strong bond. A drying period of at least 24 hours is necessary after the second coat is applied so that the adhesive may achieve its maximum strength, for it has to cope with the forces that will arise while tensioning. The drawing shows the mesh, frame and stretching apparatus at this stage of the operations.

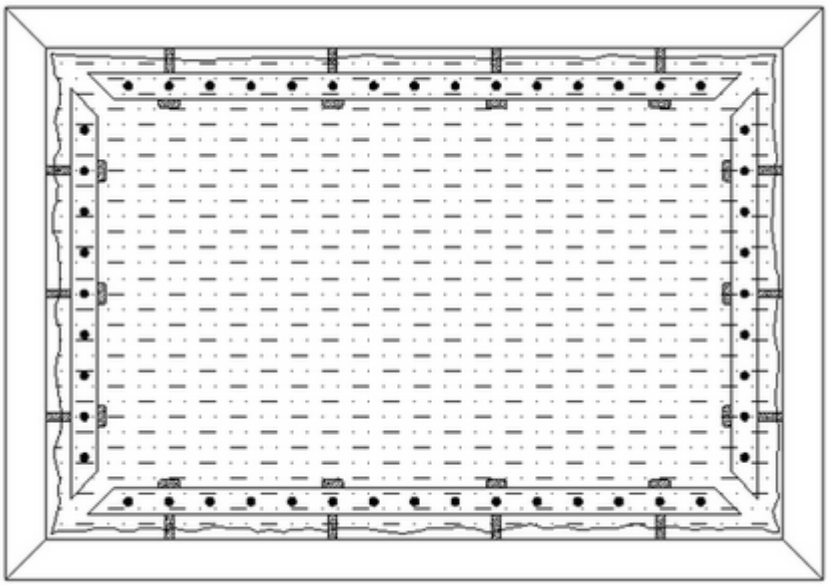

Fig. 4.5 The mesh is nailed lightly to the wooden bars, smoothed down and PVC adhesive applied to bond it in place.

After the specified drying period has elapsed, preparations may be made to stretch and tension the mesh prior to fixing it onto the frame. The wing nuts on all four sides are loosened sufficiently to release the eight spacers, which are removed. The drawbars will be free to move now, and tension is applied by tightening the wing nuts on each side in turn and working on all four sides in some balanced sequence. This means the mesh is tensioned in one direction by tightening the wing nuts on an opposed pair of drawbars, then tensioned in the other direction by tightening the wing nuts on the other pair of drawbars. The operation is repeated two or three times by alternating between the two sets of drawbars and increasing the tension progressively. A tension meter would prove invaluable in attaining the correct tautness in the mesh but is not an absolute necessity. The forces generated are resisted entirely by the PVA adhesive and not the nails, which merely served to align and support the mesh in a wrinkle free state to facilitate the application of adhesive. If excessive tension is applied the mesh will begin to tear but the adhesive bond will not be broken. Tearing is more likely to occur at the corners as this is where the tension tends to rise excessively. The usual cause is insufficient clearance between the ends of the drawbars. By leaving an appreciable gap between the ends of adjacent drawbars, tension at the corners can be kept in check.

By securing the mesh to the tensioning apparatus in two stages, using nails first and adhesive later, a cumbersome operation is reduced to a manageable one with fewer chances of something going wrong. After tensioning, it would be a good idea to allow the mesh to remain in this state for a couple of hours and re-tension it again because virgin mesh tends to undergo a degree of permanent elongation when stretched the first time and much of it occurs within the first few hours. This phenomenon occurs regardless of the type of apparatus employed for the tensioning.

The next operation is affixing the mesh to the frame. To accomplish this, measure the height of the mesh above the worktable as accurately as possible and note it down. The screen frame to which the mesh is to be adhered is placed on a sturdy, raised support on another worktable and the height of its top face adjusted so that it is 1/8” greater than the height of the mesh. To facilitate accurate measurement of these dimensions, both working surfaces have to be smooth and level. The next step must be executed carefully. Lift the mesh stretching apparatus up bodily, carry it over and poise it above the screen frame, then lower it gently over it and bring to rest on the worktable surface. The mesh would then come firmly into contact with the upper face of the frame, but the entire weight of the apparatus will not fall on it. It is important to set up the height correctly so that there will be only a marginal increase in tension before the heavy angle iron frame comes to rest on the worktable a fraction of an inch after the mesh comes into contact with the frame. If the screen frame is positioned too high, a greater part of the weight of the apparatus will fall on the mesh and cause it to tear. The illustration below provides a cross sectional view of the stretching apparatus and the screen frame after bringing them together.

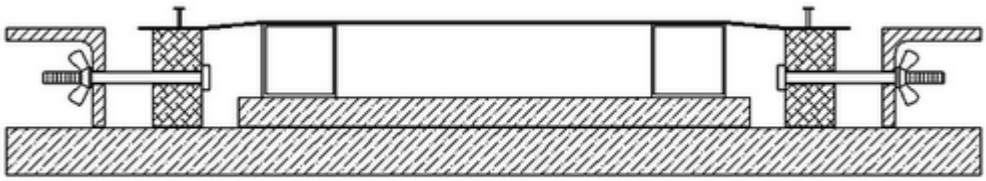

Fig. 4.6 Sectional view of mesh stretching apparatus after nailing and gluing mesh, followed by tensioning it and placing it on the screen frame. Frame adhesive is applied next.

Fortunately, there is a built-in safety mechanism to protect the mesh from overloading. The G.I. bolts connecting the wooden drawbars to the iron frame possess some freedom of movement and can tilt upwards a little if necessary, raising the level of the mesh slightly and relieving any increase in tension. In other words, the looseness or ‘play’ in the mechanism is able to prevent an excessive rise in tension as the mesh is brought down to bear on the frame. When transferring the stretching apparatus from one work surface to the other, get an assistant to share the load. If you attempt this feat single-handedly, it may result in a hernia.

After ensuring the screen frame is properly centered and oriented with respect to the drawbars, you can start applying the adhesive. As the mesh is in a highly tensioned state a strong and tenacious adhesive must be used for this purpose. In addition, printing screens get wet all the time, so the adhesive needs to be highly water resistant too. Frame adhesives have been developed to meet these conditions of service and at least three different varieties are available. The most common type is urethane adhesive that is slightly elastic and cured by the addition of a catalyst. Epoxy resin adhesive is a more rigid material that is cured by the addition of a hardener. The single component cyanoacrylate adhesive can also be used.

In the case of wooden frames, waterproof glue will serve well. Polyvinyl acetate adhesive rendered waterproof by the addition of a small quantity of potassium or ammonium dichromate works reliably. Use a one-inch paintbrush to apply the glue or adhesive onto the upper surface of the frame through the mesh. Two coats are advisable, so apply a second coat, which can be done soon after the first coat of adhesive has dried partially. Take care not to drip any adhesive onto the working area of the mesh as it will prove impossible to remove thereafter.

For metal frames, use a urethane adhesive. This two-component product cures rapidly when the catalyst is mixed into the base. Therefore, prepare the adhesive in small quantities and apply it onto the upper surface of the frame through the mesh with a plastic spatula or stiff cardboard, one section at a time and smooth it down to obtain a level finish. This adhesive will bond tenaciously to metal surfaces as well as wood. It resists solvents and exhibits high strength with a single application proving adequate. A special thinner is available to thin down and clean off surplus frame adhesive. Epoxy resin adhesives may also be employed to affix mesh to all types of frames. With this product, the resin and hardener are mixed in equal proportions. Epoxy adhesive is harder than urethane-based adhesive. The quick drying variety is always used for fixing mesh. All these adhesives are difficult to remove later when the mesh needs to be renewed.

The frame adhesive will cure fast but must be allowed to remain like that for about two hours at least. After the adhesive has dried completely, loosen the wing nuts and cut off the mesh right around the screen frame to release it. Trim off the surplus mesh neatly. Now you will have a frame with a tightly and evenly tensioned mesh anchored securely in place, which can bear a succession of stencils over a long and useful service life.

The strips of mesh still attached to the drawbars may be removed by moistening the PVA coated areas with a wet brush after pulling out all the nails first. The nails will be easy to remove as they were driven in only partway. The adhesive will soften allowing the cut off strips of mesh to be peeled off by firmly tugging on each loose end upwards. Much of the adhesive remaining on the drawbars may be scraped off with a suitable implement, after moistening again if necessary, leaving a clean surface. As these areas will be covered with adhesive every time a mesh is fixed, there is no point in laboriously removing every trace of the old adhesive. The next time mesh is secured to the drawbars, the work can be executed more speedily because the nails could be driven into the same spots.

The main advantages of this mesh stretching apparatus are its low cost and simplicity. The main drawback is the need to construct say, as many as three of these apparatuses to accommodate most of the popular sizes of screen frame in use. There is also the unavoidable delay caused by the long drying time of the removable PVA adhesive before tensioning can be applied. As there is so much to do in a screen-printing shop, you could profitably occupy yourself with some other activity during this waiting period. Much of the drying will take place overnight anyway when you will not be working. This method of fixing mesh to frame is appropriate for a shop that requires a limited number of screens for its own use. In fact, smaller shops do not need to carry a large inventory of screens as these can be used over and over again for different jobs.

When replacing the mesh on a frame, it may prove quite difficult to remove the remnants of the old mesh. If this is the case, simply sand down the contact surfaces and fix the new mesh on top of the old one. It is possible to affix mesh to two small frames simultaneously with this mesh stretching apparatus provided the work is executed with extra care. When not in use, the stretching unit may be stored by leaning it against a wall, where it will take up minimal floor space.

Chapter 5 – Baseboard

The baseboard forms the working surface on which the actual printing operation will be performed. The screen frame is hinged to the baseboard so that it can be raised and lowered with a swinging action to facilitate feeding in and removing the material to be printed. The baseboard should be placed on a sturdy table or metal framework of convenient height. It is a thick, heavy, rectangular or square piece of wood with a very smooth and level upper surface. It will have to be somewhat bigger than the largest screen frame that is to be used for printing.

The material to be printed is placed on the baseboard and the screen frame carrying the stencil is lowered into position. The lower surface of the stencil does not actually rest on the substrate but is poised about 1/16” to 3/16” above it. This is known as the ‘snap’ or ‘off-contact’ and is a crucial feature of the screen-printing technique. The gap between the two surfaces is mostly dependent on the size of the screen and the tension in the mesh. Larger screens are set with more off-contact than smaller screens and highly tensioned ones require less off-contact than weakly tensioned screens. When in the lowered position, the bottom surface of the screen should be parallel to the baseboard. The correct snap is set at one end by adjusting the height of the hinges as needed and at the other end by pasting rubber pads under the corners of the screen frame.

The hinges used to secure the frame to the baseboard are fitted in pairs to provide stable and accurate location while allowing it to swing in an arc. The pivot pins of both hinges should lie on the same axis. They should permit the frame to swing up and down freely yet constrain its movement precisely so that it always comes to rest in the same position. Several different types of hinge arrangements have been developed by screen printers over the years to allow different screens to be fitted to the same baseboard quickly and easily. Certain designs of hinges have provision for adjusting the height of the screen above the baseboard so that the correct snap distance can be set easily at that end.

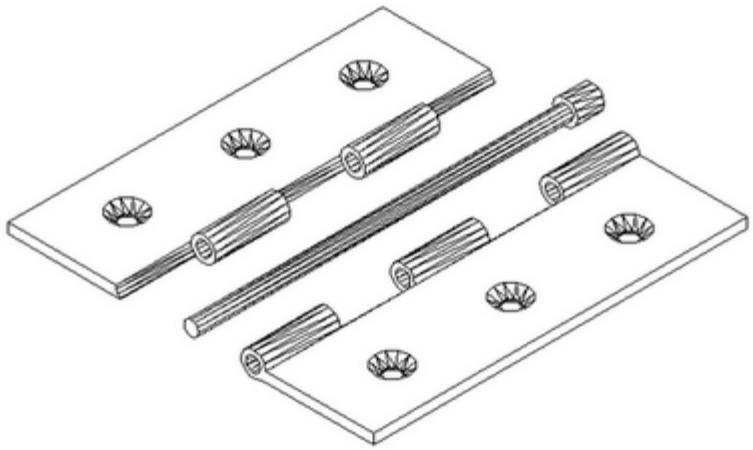

Fig. 5.1 The leaves of a removable pin hinge can be taken apart and rejoined.

Similar to the ordinary hinge used on cupboard doors is the removable pin hinge in which the two leaves can be separated by pulling out the center pin. These hinges are suitable for use with wooden frames as they can be fastened to it with wood screws. The other leaf of each hinge is screwed onto a length of timber of 1½” x 1½” cross section. This piece of wood is secured to the baseboard by means of iron bolts that pass through the holes drilled at both ends as shown in the illustration. The use of wing nuts permits the off-contact distance to be adjusted easily by allowing spacers of the required thickness to

be inserted between the baseboard and the hinge bar. Cardboard pieces of various thicknesses serve satisfactorily as spacers. The illustration below will give some idea of the setup.

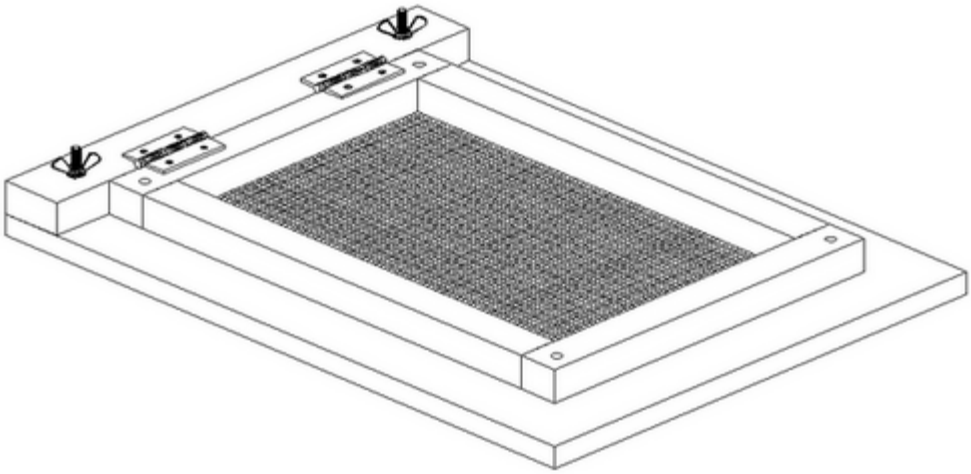

Fig. 5.2 A simple arrangement of baseboard and screen with an easily removable hinge-bar.

Removable pin hinges could also be fitted to aluminium frames with blind rivets but this would allow water to enter the hollow framework, slosh about inside and seep outside at inopportune moments onto the wet ink. Therefore, the more common practice is to employ a pair of hinge-clamps that can hold the metal frame securely yet allow it to pivot freely and facilitate easy changeover of screens. The hinge-clamp is built up of a pair of clamps, which are joined together by a heavy-duty hinge, on which they can pivot. One clamp grips the baseboard, and the other clamp grips the frame. Generally, these clamps tend to raise the frame a little too much above the surface of the baseboard due to the combined thickness of their sections so it may be necessary to keep a plywood sheet over the baseboard to raise the working surface to the correct height. The ‘off contact’ is adjusted by varying the thickness of spacers placed between the baseboard and the upper jaw of the lower clamp. Adjustable height hinge-clamps allow the screen height to be easily adjusted to accommodate articles of thick section that have to be printed. The ‘off contact’ may also be readily set at that end with these hinges. The drawings below show what a typical hinge clamp looks like and how it is installed.

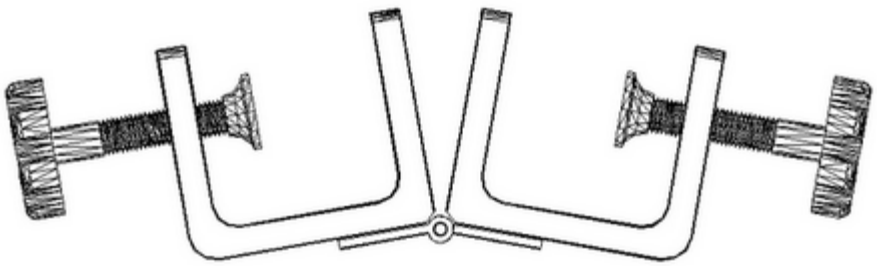

Fig. 5.3 A pair of hinge clamps used for mounting the screen.

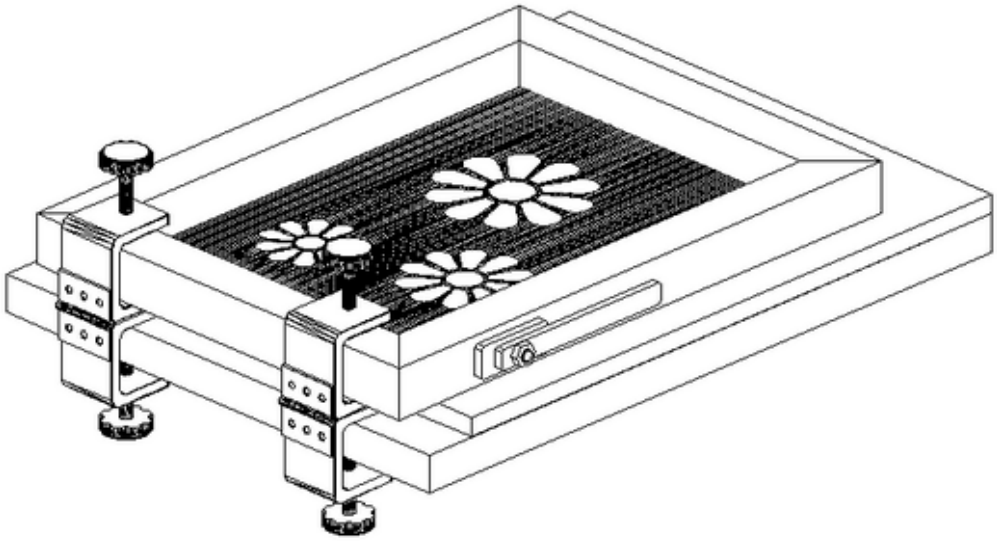

Fig. 5.4 Hinge-clamps are used to enable the screen to swing freely up and down.

A simple design of hinge clamp uses a single clamp riveted to a hinge. The hinge has to be fixed onto the baseboard with screws and the clamp holds the screen frame securely in place. This type too must be fitted in pairs but is not as convenient to use as the double clamp that can be released easily from the baseboard. Fig. 5.5 shows this design.

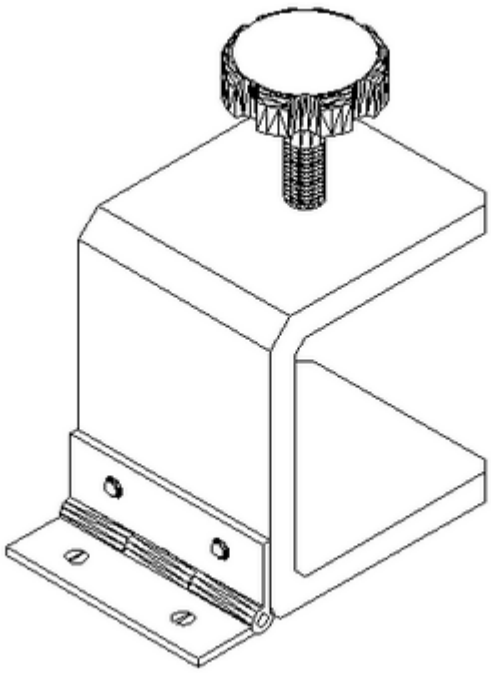

Fig. 5.5 This simplified clamp design is less convenient to use because it is fixed semi-permanently to the baseboard with screws.

Most frames are of rectangular shape, and they should preferably be held in the clamps by one of the shorter sides. This permits the use of a narrower squeegee and a longer stroke, which together result in better control when printing manually. The direction of squeegee movement is toward and away from the hinges and never at right angles to it

because the ability of the frame to resist shifting in the longitudinal direction is far greater than its ability to resist lateral forces. Any sideways movement is bound to cause a loss of registration. The screen frame must be set up properly on the baseboard with its lower surface parallel to it and with the snap or off contact set correctly. When the squeegee is pulled to make a print, only that part of the stencil that is pressed down by the edge of the blade should touch the surface to be printed. Therefore, in effect, only a line contact takes place between the stencil and the substrate. This may be a thick or thin line depending on the edge shape of the squeegee. As the squeegee is pulled, the contact line moves steadily down the screen from the clamped end to the other with the inked area on the substrate following it.

Most printers pull the squeegee towards them on the print stroke but there a few who push the squeegee to make a print. This is probably because they started off wrong and then got used to it. As in any other work, the best approach is to do things the right way from the start as it is difficult to change habits later. Better control over the squeegee, such as the angle, force and speed can be exercised when pulling rather than pushing so it would be advisable to follow this method. It also looks quite odd when you push the squeegee to make a print!

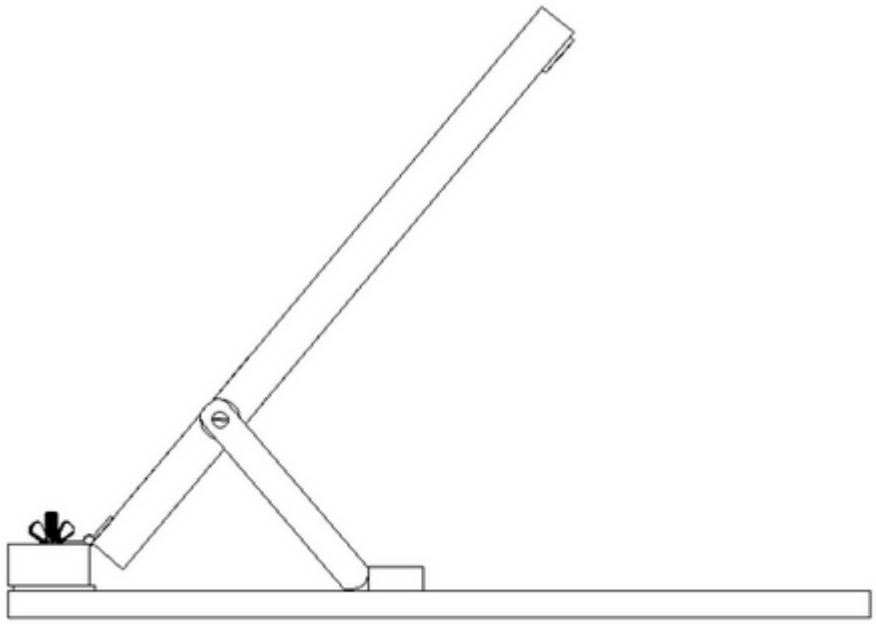

Fig. 5.6 A wooden screen propped up by a pivoting arm. Note the spacer under the hinge bar used for adjusting the height.

When printing is in progress the need to prop up the screen frame in a raised position arises constantly to enable material to be loaded and unloaded and for other reasons. It is easy to fit a simple support arm onto one side of a wooden frame as shown in Fig. 5.6 to hold the frame in an open position at an angle of 50° or 60°. To arrange this, a fiber washer is interposed between the frame and the arm, and the screw firmly tightened. Friction will hold it securely in any position allowing the screen to be propped up at the desired angle. If the frame is very heavy, a tiny block of wood may be fixed onto the baseboard to provide a positive stop for the arm.

With aluminium frames, a pivoting friction arm with a fiber washer is mounted on a small rectangular metal plate that is stuck onto one side with silicone sealant. As these frames are light in weight, the friction generated is sufficient to hold the screen in a raised position as shown in the drawing below.

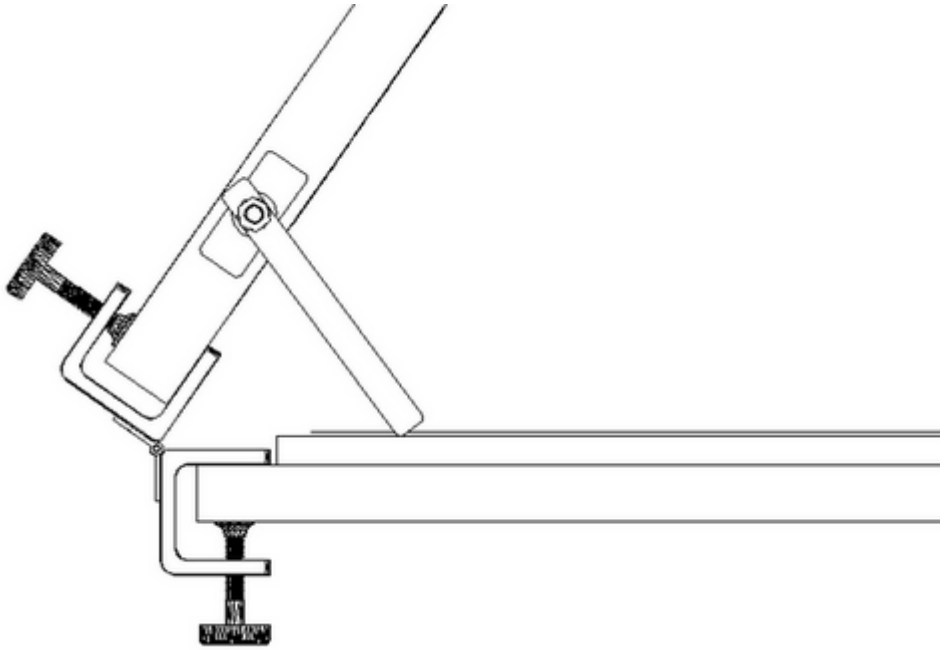

Fig. 5.7 An aluminium frame can be propped up at any desired angle by means of a metal friction arm.

High quality manufactured baseboards are available with integral hinge assemblies. As these are counterbalanced by springs, they can hold the screen in a raised or lowered position. Baseboards may incorporate other aids to printing as well. Suction provided by a vacuum pump may be employed to hold the paper securely in the correct position, preventing it from sticking to the wet printing ink and lifting up with the screen as it is raised up. The suction may be controlled by the operator with a foot pedal or automatically by the angle of the screen as it is raised and lowered.

Registration guides or stops must be fixed on the baseboard to ensure that the ink is laid down at the identical location on all workpieces of a print run. The registration guides cannot be fixed permanently since they must be movable to adjust to screens and work pieces of varying sizes. The best way to accomplish this is to fix the guides to the baseboard with adhesive tape. The usual practice is to use three guides, two of them horizontally to locate the bottom edge of the work piece and one vertically to locate its left edge as shown in the figure below. The horizontal guides are positioned at the bottom so that they face against the direction of squeegee movement during the print stroke. Using more than three stops increases the likelihood of misalignment of the work pieces. The design and thickness of the registration guides will vary according to the characteristics of the substrates to be printed, as will be explained in later chapters. Textile printing, for example, is accomplished without the benefit of any registration guides at all. The drawing below shows the disposition of the guides when printing on paper and other thin materials.

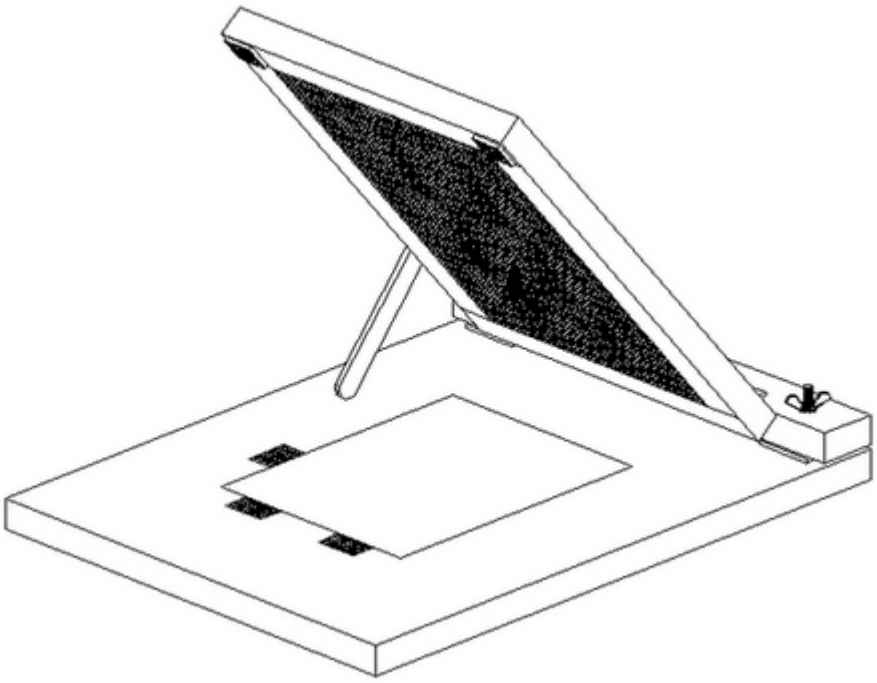

Fig. 5.8 The registration guides, slightly thicker than the paper to be printed, are taped onto the baseboard to locate the paper accurately.

It is important to keep the baseboard at a comfortable height so that the operator will be able to work the whole day without developing a backache and tiring soon. In manual screen-printing, the direction of squeegee movement is towards the operator during the print stroke. What is referred to as a ‘flood stroke’ is used to distribute the ink lightly across the stencil to ensure complete coverage of ink over the open areas. During the flood stroke, the direction of squeegee movement is away from the operator. The print stroke and the flood stroke are thus carried out alternately, towards and away from the operator. The stencil must not contact the substrate when flooding the screen. Proper flooding ensures even coverage of ink on the image areas of the print.

Chapter 6 – Squeegee

A squeegee is the tool used to force the screen-printing ink of pasty consistency through the open areas of the stencil onto the substrate below in a controlled manner. A brush cannot accomplish this task, as its bristles cannot transmit the force needed to push the thick ink through the fine holes in the mesh.

A squeegee is built up of a thick, flat, blade-like section composed of a tough and resilient material clamped securely to a wooden or metal handle. The blade was earlier composed of natural rubber and later of synthetic rubber (*Neoprene*) but now is more likely to be made of polyurethane. The reason for the popularity of polyurethane is that it possesses just the right combination of physical and chemical properties needed for this application. It is chemically inert and exhibits excellent resistance to the action of inks, solvents and most other chemicals. It is also physically stable, being resistant to swelling or softening in addition to possessing just the right degree of hardness and resilience. It is available in long strips or as cut pieces of 1cm x 5cm cross section in standard widths. Four sharp edges are available on a strip of material, two per side. When these edges become dull, they can be sharpened on a suitable grinding machine to restore the sharp, square edge or with certain types of handles removed and refitted to expose the opposite pair of edges.

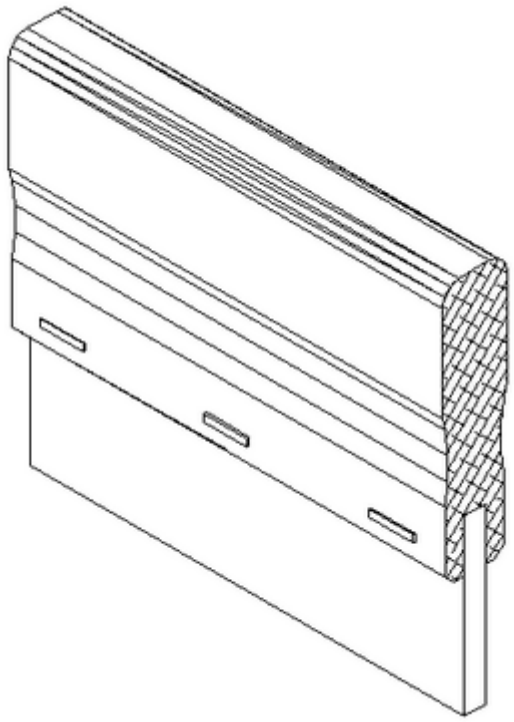

Fig. 6.1 A squeegee with a wooden handle.

The squeegee blade is fitted with a handle made of wood or aluminium extending across its full width to enable the operator to grip it firmly and comfortably, preferably with both hands so that he may guide it with complete control. Wooden handles are slotted at the lower end so the blade may be inserted and fastened by stapling it. Extruded aluminium handles may be constructed of one or more sections with small screws and nuts that pass through to clamp the blade securely in position.

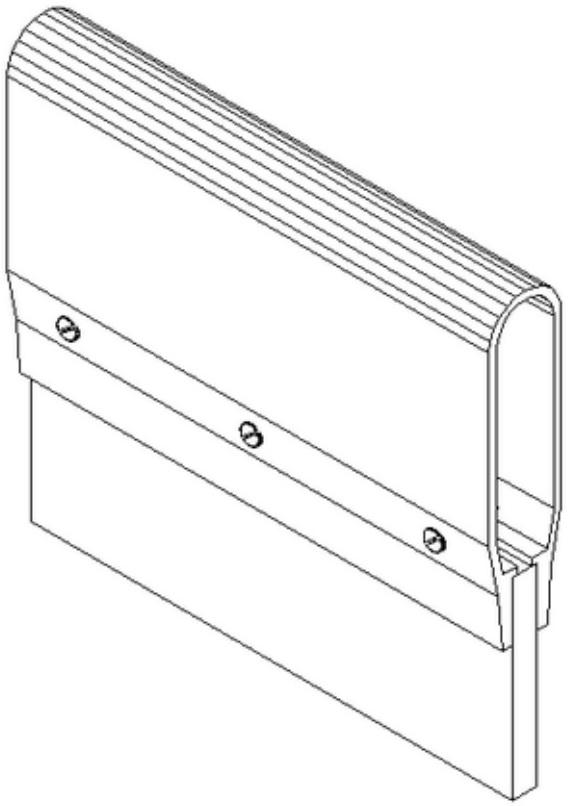

Fig. 6.2 A squeegee with an aluminium handle.

Polyurethane squeegee material is available in three hardness grades. The hardness of resilient materials is measured on a device known as a durometer. Soft polyurethane has a durometer hardness of 60; the medium grade has a hardness of 70 and the hard grade 80. Soft blade material is chosen when working with low mesh count screens and soft, absorbent surfaces such as cloth where good ink coverage is required. Squeegee blades of medium hardness are chosen for regular work on paper, board, wood and compliant plastics materials such as polyethylene and polypropylene, with intermediate mesh counts. The hard squeegees are reserved for accurate, high resolution print work on smooth, hard, non-absorbent surfaces such as the harder plastics, glass and metals using fine mesh screens. Summing up, soft blades are used on soft substrates to lay down a heavy deposit of ink while hard blades are used on hard substrates to lay down a light deposit of ink.

Another factor that influences the thickness of the ink layer is the edge shape of the squeegee blade. Sharp edges perform best for most work such as printing on paper, plastics, wood and metal by laying down a thin coat of ink and producing sharp impressions. Therefore, the edge shape is often modified to match the characteristics of the ink and substrate to obtain the desired result. For example, squeegees with blunt edges tend to lay down a heavier coating of ink and therefore used with fluorescent ink, which needs to be deposited thick to deliver the right impact. The blunt edge also works better on uneven surfaces. A pointed, ‘V’ shaped squeegee is best for producing sharp and accurate impressions on hard and smooth surfaces like glass, PCB laminates etc. Squeegees with rounded edges are preferred by textile printers as they lay down heavy coats of ink on the uneven and absorbent surfaces, producing bold and bright prints. A squeegee with a sharp edge will need to be reshaped on a grinding machine periodically.

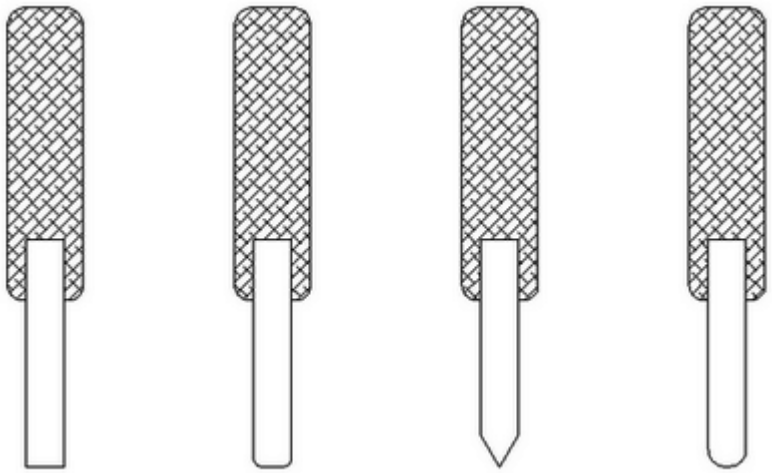

Fig. 6.3 Squeegee edges may be square, blunt, 'V' shape or round to suit the demands of different applications.

The width of the squeegee will have to be about 20% greater than the width of the image area, which means it would extend just 10% beyond it on either side. Any attempt to scrimp on this margin may result in images with clipped sides! The width of the squeegee would also need to be considerably narrower than the internal width of the frame if the mesh and stencil are to have a long service life. This is because the mesh is not as free to deflect close to the side of the frame as it is in the middle. As the squeegee repeatedly travels along the stencil pressing it down onto the substrate while overcoming the resistance generated by the off-contact feature, the greatest wear on the stencil and mesh will take place near both ends of the squeegee, as they are closer to the frame. Increasing the gap between the ends of the squeegee and the frame on either side would minimize the wear and tear in these overworked areas that often show up as two narrow strips running along either side of the path traversed by the squeegee.

The movement of a squeegee should always be towards or away from the operator. Wide squeegees are grasped with both hands when printing, but smaller squeegees may be worked with one hand. Very wide squeegees are sometimes moved by two operators standing on opposite sides of a long, narrow table when printing on long pieces of cloth such as curtaining. On mechanized screen-printing machines, the squeegee is guided and moved by motor driven arms and levers. These machines can work to closer tolerances and with narrower clearances than is possible with manual printing due to the precision with which the squeegee and other operating conditions may be controlled.

When printing, you should hold the squeegee at an angle between 45° and 60° and inclined towards you. The angle influences the thickness of the ink laid down, a lower angle laying down a heavier deposit and a higher angle a lighter deposit. During the printing stroke, press down on the squeegee to force the stencil into firm contact with the substrate and pull towards you in a smooth steady movement while maintaining the same angle. When long strokes are involved, it may be difficult to maintain the squeegee at a constant angle using only arm movements. If such is the case, you can exercise better control over it by keeping the arms steady but moving bodily by taking a step backwards. That is, instead of bending your elbows, flexing your wrists and moving the arms, which would change the angle of the squeegee, move the whole body by shifting your position on the floor.

At the conclusion of the printing run, all ink adhering to the squeegee should be scraped off with small pieces of stiff cardboard kept for the purpose. Then it must be cleaned with a rag dipped in a solvent appropriate to the ink used, wiped dry and stored flat. For water-based inks, just wash up with water. With constant use, the squeegee blade may eventually swell up and lose its stiffness and shape, leading to a lack of precision. This is because the inks, additives and solvents used in screen printing are quite aggressive. If possible, flip the blade around and use the other edge, if not, discard it and fit a new blade. Hard blades, being of denser material, possess greater solvent resistance than softer blades and are therefore less prone to swelling.

Squeegee blades are sometimes made by combining materials of different hardness. Hard material may be sandwiched between two layers of softer material to produce what is referred to as a ‘double durometer’ squeegee. It is constructed in three layers, with the hard material in the middle and medium hard or soft material on either side. The result is essentially a hard blade that is also flexible at the same time. It is supposed to confer certain advantages such as being more tolerant of uneven surfaces, providing greater control over ink flow and being less tiring to use than a hard squeegee.

The squeegee may appear to be a very simple tool but the thickness of the ink deposited is dependent on five distinct factors related to it. They are the hardness, edge shape, angle, pressure and speed. Increasing the pressure, the tilt and rounding the edge will push more ink through the screen. Increasing the speed and hardness will transfer less ink through the screen. Thus, it will be seen that changing any of these parameters will exercise an influence on the ink deposit thickness.

Chapter 7 – Drying Racks and Ovens

Printed matter, especially paper ejected from conventional presses may be stacked in piles atop each other because regular printing ink dries rapidly. This is not the case with most screen-printing inks which may take anywhere from 10 minutes to 10 hours to dry, depending on such factors as the type of ink used, nature of the substrate, thickness of the ink deposit, ambient temperature, relative humidity and circulation. Hard substrates such as metal and glass require an increased drying time after printing because of their non-absorbent nature. Porous and absorbent materials like textiles and certain varieties of wood dry slowly because they typically receive heavy deposits of ink!

For this reason, most screen-printed products cannot be stacked in a pile immediately after laying down the ink as this will lead to smudging of the print. Therefore, some means must be provided for keeping the printed output separate from each another, with sufficient space in between for the circulation of air. A workshop with production going on at full swing can spew out a considerable volume of work representing a large surface area. It is not feasible to spread out the printed matter on all the worktables, the floor of the building and every other horizontal surface. The only practical solution to this problem is to provide drying racks and cabinets to match the volume of output.

Drying racks are freestanding units of tiered construction comprising numerous horizontal shelves made of welded wire mesh or heavy plastic netting. There may be up to 50 trays stacked vertically and spaced just one inch apart with provision to prop up the trays to facilitate loading and unloading. The trays on later models may be counterbalanced by springs. The open mesh structure of the shelves allows air to circulate freely. A drying rack such as this offers a very large surface area for supporting freshly printed matter in comparison to the floor area occupied by it. The rack shown in Fig. 7.1 can be wheeled around as it is mounted on castors. As this type of rack is made by specialist manufacturers it is not cheap.

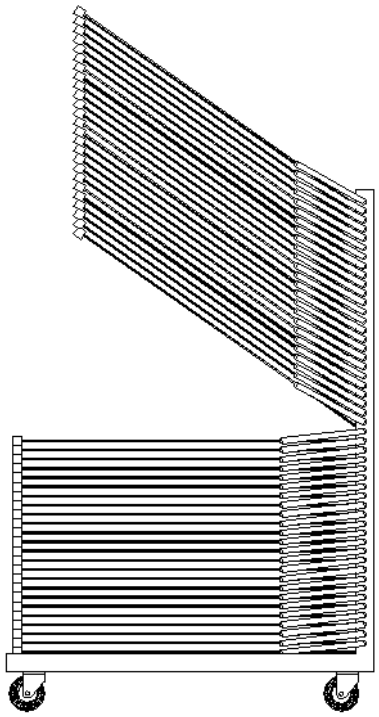

Fig. 7.1 A drying rack with 50 trays, mounted on castors.

Stationary racks with welded mesh shelves such as that shown in the drawing below are more common as they are quite easy to make. Alternatively, they could be purchased at low cost. The shelves may be removable or permanently fixed in position.

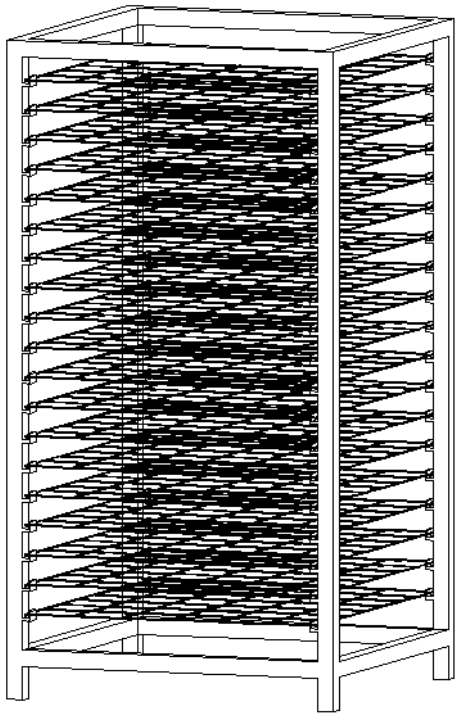

Fig. 7.2 A simple rack for storing freshly printed matter.

When printing on rigid materials such as metal labels, plastic cards or circuit boards, it may be more convenient to store them in a vertical position to dry. Wooden racks with grooves in their internal horizontal surfaces will prove ideal for this use. The rack must be adjustable for height to accommodate work pieces of differing sizes as shown in the illustration. Dozens of racks like this may be required if the volume of production is large.

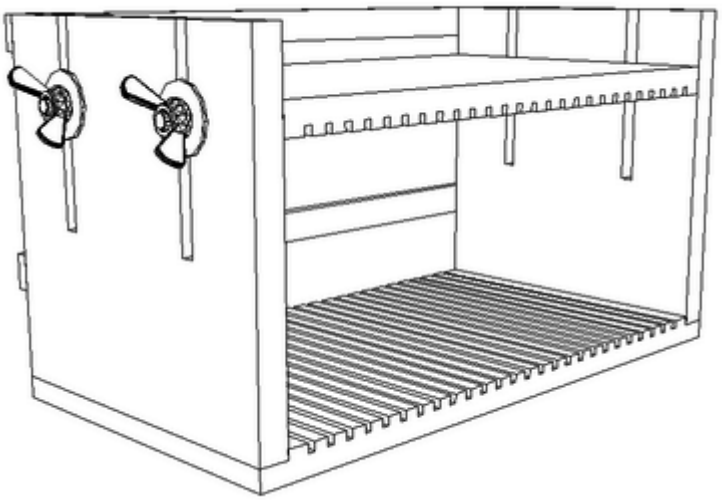

Fig. 7.3 Thin, rigid material is stored vertically after printing in this height-adjustable shelf.

The loading and removal of printed articles from racks should be conducted on a ‘First In, First Out’ basis and not in some haphazard manner. This is common sense, but a newly hired employee may not attach much importance to these things, so he must be firmly instructed to make sure he sets about it the correct way.

Whereas drying racks can prove to be a great boon to the printer, they depend on natural circulation to dry the wet ink, which does so in its own time. An enclosure equipped with a fan to provide forced air circulation can hasten the drying process and increase throughput even without a heater. When constructed of wood they are called drying cupboards, and when made of sheet metal they are known as drying cabinets. A drying oven is a drying cabinet fitted with an electric heater to warm up the airflow from the fan. They are also referred to as convection ovens as the air is warmed up by the heater and circulated by the fan. Drying cabinets and drying ovens generally serve to get rid of moisture, solvents and all volatile matter from the articles being treated. The convection oven is generally operated at moderate temperatures with the airflow through it helping to prevent overheating. It is very effective at drying ink and other materials. The oven is divided into compartments made of chromium plated or galvanized iron grills to permit the free circulation of cooling air. A typical drying cabinet is shown in the accompanying illustration.

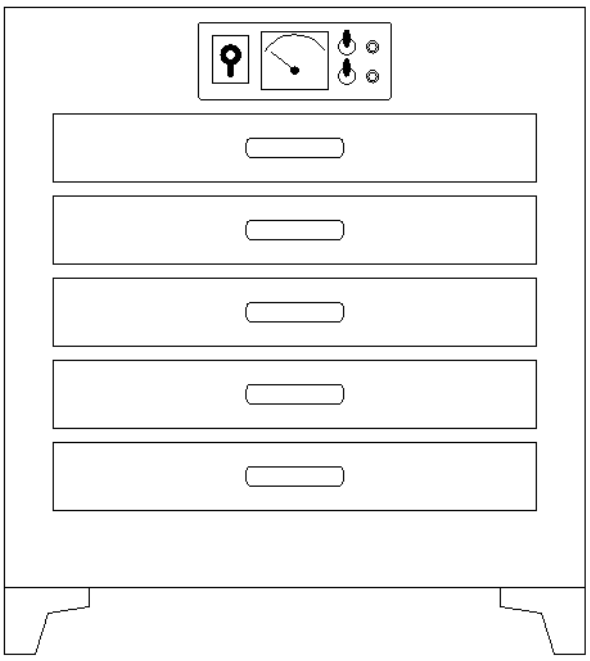

Fig. 7.4 A convection drying cabinet with heat regulator, temperature gauge and fan controls.

Wooden drying cupboards can be constructed cheaply by the do-it-yourselfer or by a carpenter. The path or paths to be taken by the circulating air and the dimensions of the cupboard must be worked out carefully on paper before beginning construction. A small electric fan should prove adequate, as what is desired is gentle airflow, not a powerful blast. Due to the large volume of air passing through the cupboard, a lot of dust would also be drawn inside and settle on the freshly inked surfaces. Covering the intake opening of the drying cupboard with filter cloth, which should be backed up by wire mesh would effectively prevent the ingress of dust. An electric heater should never be incorporated into the design of a wooden drying cupboard due to the risk of fire.

As a great deal of harmful solvent vapors are released into the air during the ink drying process, all drying racks and equipment must be located away from the main work area where the actual printing is done. The workers at the printing tables are exposed to enough fumes there and should not be subjected to additional exposure by storing the loaded racks in close proximity. The drying room must be equipped with exhaust fans to get rid of all fumes and vapor.

Sometimes what is desired is not a drying operation, which implies the removal of volatile matter but a baking or heat curing operation that is performed to harden and toughen the ink. For this purpose, an infrared or radiant heating oven will have to be employed. There are also inks that cure by exposure to ultraviolet light. These UV curing inks are used in the production of electronic components and many other types of work. A shop using UV inks would need to be equipped with a zone fitted with UV bulbs, possibly in conjunction with a conveyor assembly if a high production rate is to be achieved.

One of the simplest arrangements for drying printed products is to string up an array of plastic multifilament cords across a room, spaced apart as appropriate. Clothes pegs, hangers, spring clips or wire hooks may be used to hang the items to be dried on the lines. Garments printed with water-based inks are usually hung out to dry in this manner. A very large number of pegs, hangers, clips, etc. would be required.

The need for drying equipment starts at the pre-production stage itself where drying processes form an important part of the operational routine. Emulsion coated screens, if dried in ovens can be transferred to the exposing table quickly, thereby expediting the production of stencils. Working stencils may need to be washed and dried fast all the time and here too the drying equipment greatly assists in the smooth flow of work.

Other types of dryers are used by screen printers too. Conveyor dryers and flash dryers are discussed in Chapter 19 devoted to textile printing.

Chapter 8 – Hand Cut Stencils

The cut paper stencil mentioned in Chapter 1 will constantly shift from its position, become soggy gradually, causing fuzzy outlines and soon break down. Put simply, it will neither be reliable nor durable. Stencil material specially made for the purpose is available from the dealers of screen-printing supplies. This material is known as hand cut stencil film because it is usually cut to the desired shape by hand though it is possible to obtain faster and neater results with a computer-controlled plotter-cutter. This device is also known as a vinyl cutter and is commonly used in sign making shops. A stencil made this way is essentially a mechanical stencil as it is formed into the required shape by physical means.

Hand cut stencil films have a limitation in that their use is restricted to work involving the printing of bold, blocky shapes and lettering. They are not well suited for making stencils of complicated or finely detailed design. The chief advantage in using hand cut films is that the stencils may be produced at low cost. They are profitable even for short production runs and are commonly used for the printing of advertising banners of cloth intended for outdoor display.

All hand cut or machine cut stencil films are dual-layer products. A glassy stencil-forming layer of lacquer is supported on a clear base layer known as the ‘carrier’ or backing sheet, usually made of strong wax coated tracing paper or polyester film. To cut the stencil, the artwork is first placed on a smooth, flat working surface. A piece of stencil film cut to a size slightly smaller than the inside of the screen frame is centered and taped immovably onto the artwork with the stencil layer facing up. The stencil film is translucent like tracing paper and the artwork or lettering may be discerned through it.

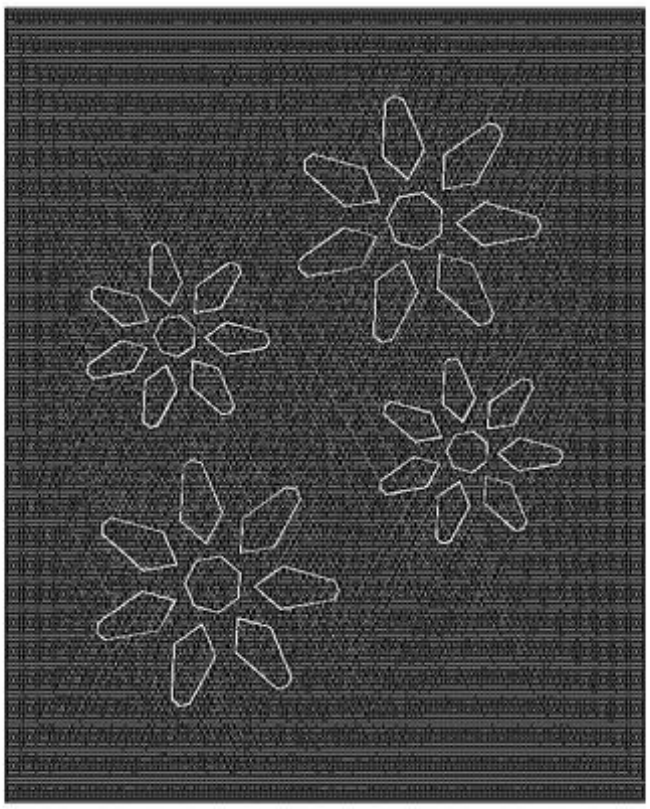

Fig. 8.1 Hand cut stencil film with the outlines of the design incised into the upper layer.

Cutting stencil film is an operation that calls for a deft hand because only the upper or active layer is incised without slicing through the carrier sheet. A stencil cutter that has a series of very sharp and renewable edges is pressed down with just sufficient force to cut through the upper layer of the stencil film and the lines in the artwork are traced out carefully with its tip. If the work is carried out skillfully, the upper layer will be cleanly incised while the backing sheet remains intact. With some practice, however, the necessary skill can be acquired within a short period. The stencil cutter should be handled with care, as the sharp cutting edge can inflict bad injuries. An incised stencil film will show the outlines of the design as shown in Fig. 8.1.

Once the cutting operation is complete, those parts of the stencil film representing the image areas are stripped off carefully, section by section. This operation is known as ‘weeding’ and once this is done only those portions of the stencil film corresponding to the non-printing areas will remain on the carrier sheet as seen in the drawing.

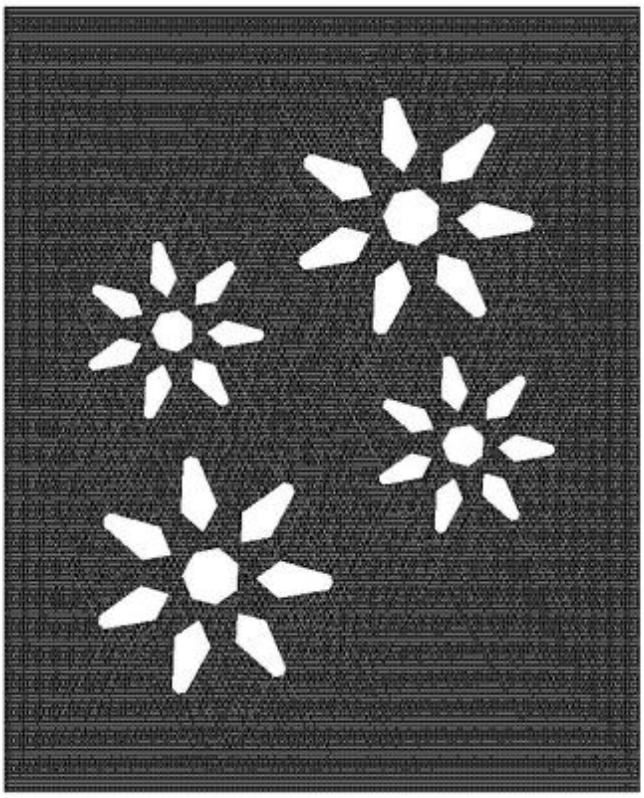

Fig. 8.2 Hand cut stencil film after peeling off the pieces from those areas through which the ink will be transferred.

There are many stages involved in making screens and every one of them has a bearing on the quality of the product, which is the final printed output. Therefore, every procedure has to be viewed as a critical operation and this applies to the transfer of the stencil layer from the backing sheet to the screen mesh too. At this point, it is important to note that there are two main classes of stencil films, a water-resistant type designed for use with water based printing inks and a solvent resistant type formulated for use with oil and solvent-based printing inks. These films come in various colors which to some extent help identify the type and intended application.

To carry out the procedure a perfectly flat tabletop is first covered with a few sheets of newspaper. The weeded side of the stencil film is kept face up on the newspaper and the screen frame is placed on it, squeegee side up. The stencil layer is adhered to the mesh by wetting both sparingly with a suitable liquid using a sponge or soft rag and pressing them firmly into contact with each other over the entire area. The liquid is applied onto the lacquer areas through the mesh. The adhering operation needs to be executed with great care as otherwise the lacquered portions may get detached from the mesh later, in the middle of production. The stencil designed for water-based inks is usually made of a tough and flexible lacquer composition and is bonded to the mesh by softening the lacquer with a special thinner that must be purchased along with the stencil film. Methyl ethyl ketone (MEK) is often one of the chief constituents of stencil adhering fluids used to fix films meant for water base inks, but other formulations may use different chemicals. Simply substituting any available solvent or thinner will most likely result in an unreliable bond and cause premature failure of the stencil. Applying too much thinner will dissolve away the stencil material, weakening it. An absorbent cloth pad should be kept handy to mop up any excess thinner in case of inadvertent over application.

The screen is given sufficient time to dry completely and harden. The backing sheet may then be peeled off gently, leaving the stencil film firmly adhering to the mesh. Water resistant block out is used to seal the border between the stencil area and frame and allowed to dry. Water based and plastisol inks may be used freely with this type of stencil but not solvent-based inks, as they will attack it. Water is used for cleaning and washing up. These stencils may be completely removed from the mesh after first cleaning out all the ink and then soaking them in a suitable thinner and dissolving them out. A new stencil carrying a different image may then be put on the mesh, which can be used repeatedly.

The procedure for adhering solvent resistant hand cut stencils to the mesh is very similar to the foregoing method, the difference being that plain tap water is used instead of the special thinner. Water and organic solvents possess very dissimilar properties in their abilities to dissolve substances. Screen printers take convenient advantage of this diversity to get their work done. They exploit the fact that materials with dissimilar properties can often work together as a compatible pair. Thus, they choose stencil materials with an affinity for solvents to print with water base inks and stencil materials with an affinity for water to print with solvent base inks. This way, the inks will not attack or dissolve the material of the stencil.

The solvent resistant stencil placed in close contact below the mesh adheres to it when both are lightly moistened with a damp sponge and firmly pressed down all over. The stencil is in fact composed of a material that is soluble in water but is highly resistant to the action of most organic solvents. When dampened with water, it yields slightly by softening, allowing the filaments of the mesh to embed themselves in it when both materials are pressed together. The adhered stencil must not be allowed to remain wet for too long and is therefore promptly dried with absorbent tissue or newsprint. A strong bond should develop when the screen has dried completely. The backing layer may then be peeled off carefully and the open border surrounding the stencil filled in with a block out of similar composition. A stiff plastic or cardboard piece is used for this purpose and the block out should be leveled smoothly on both sides. When the border has dried, the screen may be used to print with almost all solvent-based inks. As one type of stencil material cannot resist every type of solvent being marketed today, stencil films too are made of variable composition to answer every need.

Newer solvent resistant cut stencils may be attached to the mesh very simply by placing them emulsion side down onto the bottom surface of a thoroughly wet screen. A sponge is moved all over the plastic backing applying light pressure. The moisture softens the stencil material, which adheres to the mesh when pressed down. The screen is turned

over, placed on a flat surface and again smoothed out with a sponge. Any remaining dampness is blotted out with dry newsprint from the squeegee side. A fan may be directed onto the screen to hasten drying with a stream of cool air and when fully dry, the backing sheet may be peeled off. Screens with this type of stencil are cleaned with PVC thinner or similar solvents to suit the differing characteristics of the various printing inks used. Nitrocellulose (NC) thinner made for thinning automotive spray paint is too strong for cleaning up printing screens and should not be used. NC thinner may be identified easily by its much stronger odor.

Water cannot be used for cleaning and washing up a solvent resistant film stencil as this material, being soluble, cannot resist it. In fact, water is used to wash off the stencil material when reclaiming the screen. Therefore, screen wash liquid based on organic solvents must be used to clean up the stencil and screen after work.

An older type of hand cut stencil made of a shellac composition was transferred to the mesh by the application of heat. The design was cut on the stencil film and after weeding, was placed on a flat support in contact with the lower mesh surface of the screen. The upper surface of the mesh was covered with a sheet of paper and a clothes iron set at a medium heat placed on it within the well of the screen and moved around over the entire stencil area. The heat passing through below partially melted the shellac and caused it to stick strongly to the mesh. The paper was removed, and the ironing continued until all the shellac-covered areas on the mesh attained a uniform color. The backing paper was then peeled off when everything had cooled down to room temperature. The shellac stencil was used with water-based inks and cleaned by washing in water. Denatured alcohol or turpentine was used to remove the shellac and reclaim the screen. Shellac based stencils are no longer popular as they tend to become brittle after some time.

Most of the problems encountered with cut film stencils are caused by poor adhesion between the mesh and the stencil. The stencil can maintain its integrity only so long as it is securely bonded to the mesh. If it becomes detached at any spot, the stencil will soon break down there, as it is not being supported properly. Therefore, great care should be taken to ensure that these two components have adhered to each other perfectly before commencing production.

It is necessary to add a finishing touch to the printing screen before the work can be considered complete. Screen printing inks, printing additives and cleaning solvents are aggressive substances that exert a deleterious effect on the frame adhesive holding the mesh in place. Repeated exposure to these agents may weaken the adhesive, causing it to soften and lose its grip on the highly tensioned mesh, allowing it to detach from the frame. The customary method of dealing with this issue is to apply frame tape both inside and on the lower surface of the frame. Frame tape may be made of plastic-coated aluminum foil or a heavy grade of buff colored paper. The tape is applied to the internal well of the frame by cutting out four lengths to the correct size first. Each strip is folded along the middle, then one half is stuck onto the internal sidewall of the frame and the other half is stuck to the mesh. The adhesive covered area on the lower surface of the mesh is also covered up with frame tape securely to protect it from aggressive chemicals. The tape should extend into the mesh area by about half an inch. Wooden frames with the mesh secured by nails should also be covered with frame tape, to prevent ink from getting in between the mesh and the wood and accumulating as a hard deposit. Ordinary paper and plastic tapes sold in stationery shops are not suitable for this purpose. Screen printer’s frame tape must be used. The screen will now be ready for use.

Chapter 9 – Block Out Stencils

An alternative to stencils made from film are those made with block out. These stencils are prepared by applying a liquid block out medium onto the mesh on which a design has been traced out. The medium is deposited onto all the areas outside the design in one of two ways, as will be described shortly. When the block out dries, it hardens and seals the openings of the mesh in the treated areas. The materials traditionally used for this purpose and now considered obsolete were glue, shellac, lacquer, varnish and collodion. These substances possessed quite dissimilar properties and had to be chosen carefully to ensure compatibility with the equally divergent properties possessed by the printing media such as water based, oil based or solvent based inks.

A block out stencil is prepared as follows. The artwork is kept on a smooth, flat, level surface and the screen placed on it with the design centered. The artwork, which cannot be too intricate, is traced onto the mesh carefully with a very soft pencil or a fine felt pen. The screen is then lifted off the artwork and kept on supports in a slightly raised position so that the areas to be coated do not touch the surface below. For water-based inks, a waterproof block out medium such as shellac or lacquer was chosen and for oil and solvent based inks, glue was used. The current practice is to make use of modern formulations that are also used for correcting, touching up and filling in the borders of stencils, as they are made especially for this sort of work. The products are available in both water resistant and solvent resistant forms.

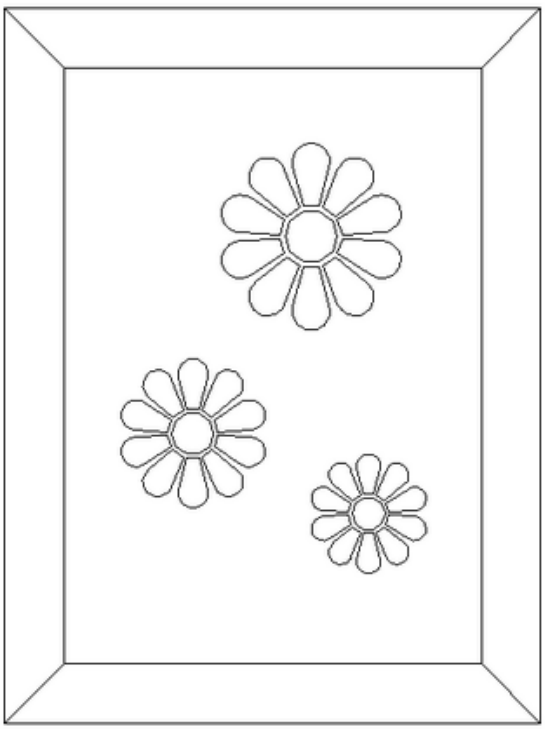

Fig. 9.1 The outlines of the artwork placed below the screen are traced onto the mesh with a fine tipped felt pen.

The selected block out medium is applied carefully with an artist's paintbrush as a thin coat just outside the borders of the tracing. A wider brush is used to apply it to all the broader expanses of the non-printing areas. It helps to have an assortment of brushes for this work. It is preferable to use a fine mesh fabric, as this will keep the liquid medium clinging to it tightly. A thin, uniform coating will give the best results. The entire non-printing surface of the mesh should be covered with block out right up to the inside walls

of the screen frame. The finished work should be held up and inspected against a light for weakly covered areas, pinholes etc. and any faults rectified. The screen should be supported at both ends in a horizontal position with the squeegee side facing up and left to dry fully in a dust free place. The brushes should be cleaned properly, dried and stored carefully. The accompanying drawings show the screen after tracing the outlines of the design and after applying the block out medium.

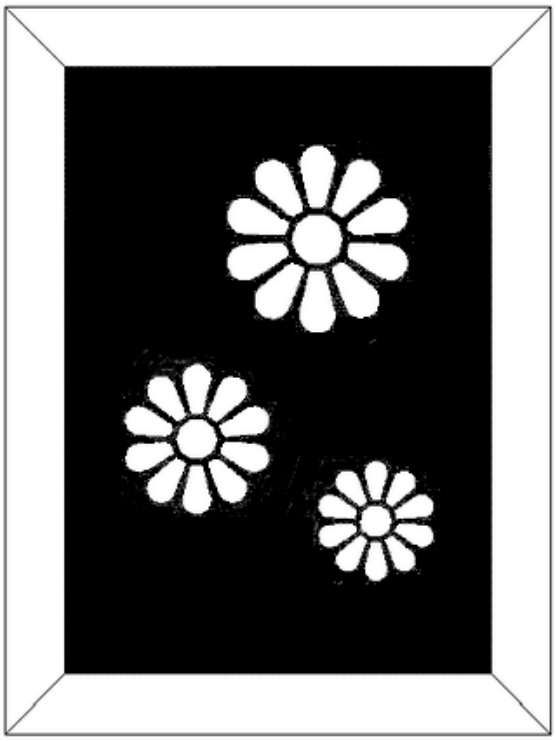

Fig. 9.2 The block out is applied carefully onto all the non-printing areas surrounding the traced outlines.

The production of blocked out stencils such as these require only some mechanical aptitude because the areas to be filled in are clearly marked out by the tracing and it is only necessary to be guided by the lines when applying the block out solution. Professional artists who possess great talent may choose to draw freehand directly on the mesh by using a slightly different method to create stencils that can print out limited edition works of screen-printed art. These prints possess a spontaneity and character that can never be emulated by a traced-out image. The artist adopts a somewhat different approach to make these screens. Instead of painting on the screen directly with block out, he uses a substance known as tusche (pronounced **Toos-sh**). Some old books on screen printing often devote several pages to explain the properties of tusche and the various and elaborate methods of preparing it. As this material is hardly ever used now for commercial screen-printing work, we will keep the explanation short.

Tusche is available in various forms such as solid cakes that must be dissolved in water first or as a prepared liquid, both of which can be painted on with artist's brushes. Tusche is also available in the form of crayons or pencils, and these are easier to use than a brush as they do not lead to a mess. Tusche is a water repellent substance of variable composition made up essentially of some black pigment and a waxy or greasy material. The solid form may be dissolved in water with some difficulty, but it is freely soluble in turpentine. Tusche was also employed by lithographers for certain types of lithographic printing. The tusche, depending on its form, is either painted on with a brush or drawn with a crayon so that it blocks up the openings in the mesh. What has been put on the

mesh now represents the actual artwork created by the artist. When the tusche has dried fully, glue is poured onto the surface of the mesh and spread evenly all over it with a stiff cardboard having a straight edge. All surplus glue is removed, and the coated mesh inspected for defects, which if present, are corrected. The screen is now set aside to allow the glue to dry and harden.

An examination of the screen would show that the image drawn by the artist is represented by the tusche-covered areas with the remaining areas completely blocked out by glue. There may be a thin coating of glue on the tusche-covered areas too but due to the greasy nature of the latter, the former will have only a tenuous hold on it. The tusche may be dissolved with turpentine and removed from the areas covered by it to open up the screen. To do this a rag is soaked in turpentine and rubbed over the tusche-covered areas from both sides. The screen will open up gradually as the tusche dissolves in the turpentine and any thin coating of glue covering the tusche will also be removed at the same time. By drawing on the mesh directly with a temporary medium like tusche and sealing up the remaining areas with a block out, it is easy to prepare a printing screen in which the open areas accurately replicate the original brush or crayon strokes of the artist. Therefore, when a print is made with such a screen, the nuances of the artist's hand movement are reproduced faithfully. If the artist were to paint his design on the mesh directly with block out, the prints made from the screen would bear an inverted or negative image of his handiwork.

A screen blocked out with glue cannot be used with water-based inks, its use being restricted to oil based and some solvent-based inks. All screens should be cleaned thoroughly when the printing runs have been completed. Surplus ink left on the screen should be scraped off gently with a piece of cardboard and the screen wiped clean with a rag dipped in thinner or screen wash to remove the ink without affecting the stencil.

Liquid block outs such as glue, shellac, lacquer and varnish are no longer used by commercial screen printers, but hobbyists and artists do use them occasionally. Modern stencil making materials are more convenient to use and being more effective and dependable, produce superior results. They are now used in combination with computerized image processing techniques, and this has rendered the old methods obsolete. The traditional processes are described here briefly for the record and to convey some idea about the evolution of stencil making techniques.

Frame tape must be applied to screens made with block out stencils just as for film stencils and indeed to all printing screens irrespective of the type of stencil used. The purpose of the tape is to keep inks and solvents away from the frame adhesive and in the case of wooden frames from the wood itself. The tape also blocks ink from getting onto the underside of the screen through any indiscernible openings in the border area between the stencil and the inside wall of the frame and marking unintended areas on the article to be printed.

Chapter 10 – Mesh Preparation

The primary function of the mesh on the screen frame is to act as a support for the stencil that is usually made up of a very large number of discrete elements of widely differing surface areas. A complex half tone stencil made with photosensitive material may be comprised of hundreds of elements separated from each other and connected only to the mesh. In either case, the mesh must do more than simply support the stencil; it should anchor every part of the stencil securely in position and prevent it from shifting or becoming unstuck. Unfortunately, polyester monofilament, which is the most commonly used material for making mesh, possesses a very smooth and slippery surface that is not conducive to good adhesion. Therefore, it becomes necessary to subject the mesh to some special treatment to promote stencil adhesion.

It may be argued that the bond between the stencil material and the surface of the mesh need not be perfect since the former encapsulates the latter and thereby locks itself into the structure of the mesh. This argument applies only to liquid emulsion coated stencils and only to a limited extent. In this instance, the mesh is embedded within the stencil that covers it on both sides so that it is difficult to separate the two. This, however, is true only for large, blocky image areas. Where narrow lines, tiny dots and other fine details are concerned, these are too small to lock themselves into the weave of the mesh. The stencil then is entirely dependent on good adhesion to keep its smaller elements from getting detached and falling off one after the other.

In the case of photosensitive stencil films, of which there are two varieties, the bond between the two materials is not very strong as only one side of the film is in contact with the bottom of the mesh. There is little physical interlocking between direct stencil films and the mesh. In the case of indirect stencil films, there may be no interlocking at all.

It is thus evident that perfect adhesion between the mesh and the stencil material is a pre-requisite to achieving a consistently high print quality and a long and useful service life from the printing screen. To ensure reliable adhesion the mesh is subjected to two special treatments to render it more receptive to the stencil material. The first treatment involves roughening the mesh lightly so that the stencil material would ‘key’ to it, while at the same time increasing the surface area available for adhesion. A composition commonly referred to as ‘Mesh Prep’ is employed for this treatment. The product uses a very fine abrasive suspended in a liquid or gel medium to abrade the surface of the mesh mechanically. Mesh prep is highly caustic and therefore care must be taken to avoid contact with the eyes. It is also hard on the skin and so caution must be exercised when handling it.

To use the mesh-roughening compound, the screen is first wetted, and mesh prep dabbed on it in several places. A nylon or polyester brush with soft bristles, specially made for this type of operation, is moved in a circular motion all over the screen, scrubbing its surface with the compound. The scrubbing is repeated on the other side and the screen is allowed to stand for two or three minutes. Both sides of the screen are washed thoroughly with a powerful spray of water to remove all traces of the roughening compound. The mesh roughening operation is usually carried out on brand new mesh that is to be used for the first time. It is not employed routinely on every occasion when an old stencil is removed, and a new one put on. Once a mesh has been roughened, it stays that way a long time so that a series of four or five stencils may be put on it in turn before it needs to be treated again. Frequent use of mesh prep will weaken the mesh. If stainless steel mesh is to be used in the screen, then that too must be roughened with mesh prep before being coated with emulsion as the strands usually have a mirror finish

that does nothing to promote good adhesion. The drawing below shows a screen being subjected to this treatment.

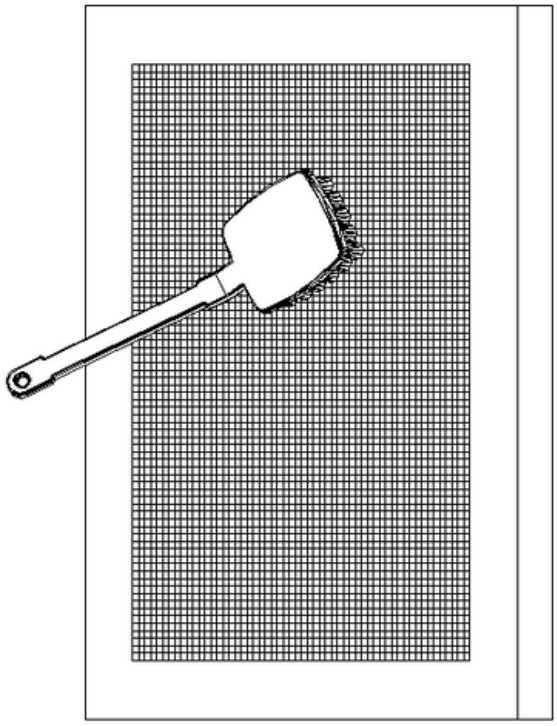

Fig. 10.1 The scrubbing brush is worked with a circular motion to roughen and degrease the screen.

The other operation performed on mesh to improve stencil adhesion is de-greasing. Both new and used mesh must be de-greased, as they generally tend to be covered with oily residues. The degreaser contains a powerful detergent that helps to remove all traces of oil, grease, dirt and dust from the mesh. It also contains a surfactant to improve its wettability, which is achieved by lowering the surface tension of the water. The procedure for degreasing a screen is very similar to the one employed earlier for roughening. The screen is wet first, and degreaser applied to it with a rag. A screen scrubbing brush is used once again to rub over the entire mesh with a circular motion. The other side of the screen is also worked over and allowed to stand for a couple of minutes. A powerful spray of water should be used to wash away all traces of degreaser by working from both sides. If a thin film of water clings to the screen uniformly and covers all the openings without any break, this would indicate a pristine surface.

Some types of stencils are put on the mesh while it is still wet from the degreasing rinse whereas other types are applied onto the dry mesh. Wet or dry, the surfaces of the cleaned mesh should never be touched by hand, as this has a bad effect on adhesion. The stencil must be put on the mesh as soon as possible after the degreasing operation, if necessary, after drying it because the surface of a screen that is kept lying around will soon become contaminated. A product is available that acts as both a mesh abrader and degreaser. The combined action of this product helps save time when treating new mesh but repeated application on used mesh will weaken it. Mesh may be degreased any number of times without weakening it but abrading results in erosion on a fine scale that can wear out the yarns soon if it is performed routinely regardless of the need for it. Use separate brushes for applying mesh prep and degreaser.

Chapter 11 – Direct Emulsion Stencils

Hand or machine cut stencils and block out stencils are classed as mechanical stencils as the pattern is formed into the desired shape entirely by physical manipulation. Today, the far more popular method of making stencils is based on photochemical reactions that are initiated by the action of ultraviolet light on certain photosensitive materials. Ultraviolet light has the remarkable property of inducing and promoting chemical reactions in susceptible materials by acting as an intangible catalyst. While there are many classes of photochemical reactions, the one that is of interest to the screen printer is the type of reaction that converts a soluble material into an insoluble form while at the same time toughening it. A number of compositions that undergo this type of change are available and all of them include a sensitizer in the formula to render the base material susceptible to the action of UV light. When these materials are marketed in liquid form they are known as stencil emulsions, but they are also available in the form of thin sheets known as stencil films.

Stencil emulsions are rather viscous liquids applied as thin, uniform coatings onto the taut mesh of the screen frame. The thickness of the deposit may vary considerably to suit the application with thick stencils being built up layer by layer, allowing each coat to dry before applying the next one. The drying operation must be conducted in a dark room or enclosure with the screen supported in a horizontal position. A filtered stream of cool or warm air may be circulated to hasten drying but never hot air. If the emulsion coating is examined closely when completely dry, it will be seen that the mesh is fully covered and only the emulsion is visible on either side. Thin coatings after drying will tend to conform to the weave pattern of the mesh. The dried emulsion will remain soft and soluble at this stage and wash off easily if immersed in water.

The deposited coating on the mesh being photosensitive will be able to perform ideally as a screen-printing stencil if it is exposed through a positive film and developed properly. The positive may be a sheet of tracing paper or plastic film on which the subject matter is represented in the form of light and dark areas. The exposure is carried out by placing the positive in close contact with the emulsion coating and placing both under an ultraviolet light source. The invisible UV rays that pass through the clear areas of the positive film strike the emulsion underneath and acting in conjunction with the sensitizer bring about a change in the chemical structure of the base material, causing it to become hard, tough and insoluble. Those parts of the emulsion covered by the dark, opaque areas of the positive are shielded from the action of the UV rays and so remain soft and soluble, as they do not undergo any chemical change. The positive is removed, and the screen washed under a firm spray of water. This causes the unexposed, soft areas of the emulsion to wash off leaving the exposed, hardened areas of the emulsion intact and locked onto the crisscrossing filaments of the mesh. What is left on the mesh now is a photo-imaged stencil or photo stencil for short, which bears an exact likeness of the pattern on the positive, the open areas of the former perfectly matching the dark areas of the latter. After sealing the bordering area with the same emulsion or some suitable block out and hardening it, the screen frame should be taped properly. It is now possible to use the screen to make prints.

It is this curious property of changing from a soft, soluble substance into a tough, insoluble material when exposed to the action of UV light that makes photo stencil emulsion such a useful product to screen printers. The formulation of these emulsions can be simple or complex. It is even possible to prepare this emulsion at home. Some very old formulas used glue, gelatin or albumin as the main ingredient and ammonium or potassium dichromate as the sensitizer. They yielded photosensitive coatings that after curing were known as chromated proteins. The coatings were also used to protect iron

and steel from rust and as they were acid resistant, were used in the production of metal labels and badges as well. A much-improved recipe is based on polyvinyl alcohol, polyvinyl acetate or a mixture of both, sensitized with dichromate. This formula yields a more pliable coating when cured and is therefore more suitable for making screen printing stencils. A small quantity of this emulsion may be made by mixing equal parts of polyvinyl acetate (PVA) and polyvinyl alcohol (PVOH). A solution of ammonium dichromate is added and stirred well until the mixture is the color of vanilla ice cream. It is the presence of chromium in the compound that is responsible for the sensitizing effect. Ammonium dichromate has slightly higher chromium content than potassium dichromate per unit weight. The addition of even a small quantity of water will lower the viscosity of the emulsion markedly and so care should be exercised when thinning. Dichromates are often referred to as bichromates by the trade, but all the chemistry textbooks and reference books use the former spelling, which is the correct one.

The homemade photo stencil emulsion serves admirably for making experimental screens by beginners to this field. It may also be used on organdy mesh to make very economical screens for limited production printing runs of outdoor displays. Incidentally, this emulsion performs well as a strong waterproof adhesive provided it is given sufficient time to dry and harden properly. A disadvantage of this concoction is that it does not keep well and therefore the sensitizer should be added just before use.

Commercial photo stencil emulsions are manufactured with far more sophisticated formulas to ensure reliable and consistent results while offering greater sensitivity to minimize exposure times. With these emulsions, it is possible to make stencils that are more durable and better able to withstand the rigors of high-volume production. They are usually a mixture of polyvinyl acetate (PVA) and polyvinyl alcohol (PVOH) with various additives to confer the desired properties needed for satisfactory performance. Photo cured polyvinyl acetate possesses excellent water resistance but exhibits poor solvent resistance. Polyvinyl alcohol, in marked contrast, has excellent solvent resistance but displays poor water resistance. The proportions of these two constituents are varied to suit the intended use. Water resistant emulsions are used when water-based inks are employed such as with textile printing using pigment and binder. Solvent resistant emulsions are used on screens made for printing with oil, solvent and other non-aqueous inks. A third type of ink known as plastisol can be used with either type of stencil.

Commercial photo stencil emulsions also differ in the type of sensitizer they employ. A high-quality emulsion will never use dichromate but a more advanced material as sensitizer. One disadvantage of dichromate is that emulsions sensitized with it suffer from a notoriously short shelf life. Dichromate particles if breathed in can cause severe irritation of the mucous membranes of the respiratory tract. One type of sensitizer, based on a diazonium compound and called ‘diazo’ for short, gives better results and is safer than dichromate, which is carcinogenic. Diazo sensitized emulsions will keep longer after mixing and possess a wider exposure latitude. A diazo sensitized emulsion also changes color when exposed to UV light. After exposure there will be a distinct difference in color between the exposed and non-exposed areas, which correspond to the non-image and image areas, respectively.

A photo stencil material with different characteristics is known as photopolymer emulsion. This light sensitive plastics material is put to extensive use in several branches of industry. It is a single component product as the sensitizer is added and mixed at the manufacturing stage itself. The pre-sensitized emulsion is sold in lightproof, black plastic containers and is available in solvent resistant or water-resistant forms to suit the type of printing ink. Photopolymer emulsions contain what is known as an SBQ sensitizer that is more sensitive to light than diazo and therefore exposes faster. Exposure timing is more critical with this type of emulsion.

A third class of emulsions referred to commonly as ‘dual cure’ is a hybrid type combining the best features of the diazo and photopolymer emulsions. They possess properties that fall midway between the two different types of emulsion and exhibit good water and solvent resistance. They have a wider exposure latitude and are less costly than pure photopolymers. As the product is packed in two parts, the sensitizer must be added and mixed just before use.

The main ingredients of stencil emulsions are organic compounds possessing a molecular structure in the form of long chains. There are myriads of long chain molecules held together rather loosely so that they are free to slide over each other in the uncured state even after drying hard. When the material is in this condition, it is rather weak and incapable of resisting the action of water and solvents. When a layer of emulsion is dried and exposed to the action of ultraviolet light in the presence of a sensitizer, a photochemical reaction takes place. The effect of this reaction is to interlock the long chain molecules and bind them together by the formation of transverse links. This is known as a cross-linking reaction, which is a common process in polymer chemistry where it is generally induced by the application of heat and pressure in the presence of a catalyst. The cross-linking reaction will always result in a dramatic improvement in the physical properties of the material subjected to this treatment, such as greatly increased strength, toughness and resistance to the action of water and solvents. This happens because now the long chain molecules are not free to slide past each other, being restrained by the transverse links.

Photopolymer emulsion supplied in a pre-sensitized state has a long shelf life of at least a year. Diazo and dual cure emulsions have a shelf life of 12 to 18 months as supplied but after mixing in the sensitizer cannot be kept for more than 4 to 6 weeks as they will degrade and rapidly lose their photosensitivity. Storing the prepared emulsion in a refrigerator at a temperature of 4 to 8 degrees Celsius will extend its shelf life considerably. Overcooling must be avoided, as the formation of ice crystals will ruin the product.

An important attribute of photo emulsion is its solids content. This can vary from about 35 to 55%. The solids content of the liquid emulsion is very important as it determines the shrinkage during drying. When the proportion of liquid comprising mainly water and other volatile solvents is high, excessive shrinkage occurs during drying, resulting in a thin covering of solid emulsion on the mesh. This thin deposit will naturally tend to duplicate the texture of the mesh. Fine inspection will reveal a surface finish of bumps and hollows corresponding to the knuckles and openings of the mesh. A print made with a stencil possessing these characteristics will not yield good edge definition. Suppose an image with a smooth outline is to be printed. If this image is printed with a stencil that has assumed the texture of the mesh, the outline will not be reproduced smoothly but be bounded by a series of tiny, irregular scallops. That is because the ink would be forced sideways into the numerous tiny depressions on the bottom surface of the stencil by the action of the squeegee. The only way to prevent this from occurring is to make sure that the lower surface of the stencil is perfectly flat and smooth so it will form a tight seal against the substrate.

This is why the solids content of photo emulsion matters so much, because it can influence the smoothness and flatness of the stencil formed by it. It is possible to obtain better results with emulsions of lower solids content by applying multiple coats, allowing each coat to dry before applying the next. This way the hollows can be filled in and leveled out gradually, but this is a time-consuming exercise. The better approach is to use thicker emulsion. Details regarding the solids content are usually provided in the manufacturer’s data sheet along with other information.

During the earlier days wide, flat paintbrushes were used to apply emulsion onto the mesh. This was a rather slow way to do the job and resulted in coatings that varied in thickness. The scoop coater, sometimes called an emulsion trough, which was developed later, gave thinner and uniform coatings enabling the work to be performed in a fraction of the time. Coatings of uniform thickness are easier to expose because all areas of the emulsion require the same exposure and therefore cure at the same rate. An even coat will reproduce detail better and have more sharply defined edges. The scoop coater is a semi-circular trough capped at either end, with a rounded lip on one side and a fine, sharp edge on the other side, as shown in the illustration. Scoop coaters are available in various widths, so it is necessary to have a matching one for each size of screen frame used in the printing shop. They are usually made of aluminium and should be about 1 to 1½ inches wider than the image and 1½ to 2 inches narrower than the internal width of the screen frame. The width of the coating will usually be about a quarter inch narrower than the width of the trough. The coater has two fins at the bottom extending across its full width to support it in a level and stable attitude on a horizontal surface to ensure easy filling and prevent spillage of the emulsion. If the emulsion is to remain in the scoop coater for any length of time, it should be kept covered with a piece of cardboard to protect it from light and to prevent dust from settling on it.

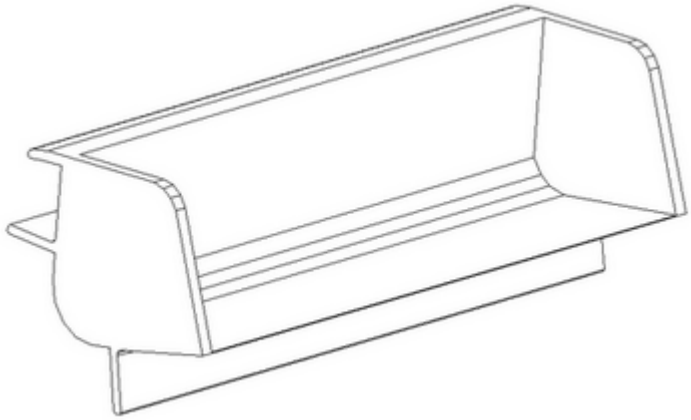

Fig. 11.1 The scoop coater has a fine, sharp edge to help lay down a thin and even coating of emulsion.

The emulsion coating should be applied onto the mesh of the screen frame soon after degreasing and drying it. To do this the screen frame is leaned against a vertical surface at an angle of about 10 to 15 degrees and secured in position firmly but in such a manner that it may be released quickly to allow it to be flipped around so that the other side can be coated as well. The flat side of screen should be coated first followed by the squeegee side. The emulsion is prepared by mixing the two components in the correct proportions and stirring thoroughly in a clean container. The instructions may vary broadly and will be specific to that product. In the case of one part, a.k.a. ‘one pot’ photopolymer emulsion, it is recommended that the contents of the pack be stirred thoroughly before use to ensure homogeneity. After preparation, the emulsion is allowed to stand for some time in the covered mixing vessel to permit any trapped air bubbles to escape.

The scoop coater is placed on a level surface and the estimated quantity of emulsion and a little more poured into it slowly, to avoid introducing air bubbles. All required materials are gathered and kept handy to avoid interruptions while the work is in progress. One item that is often overlooked is a rag to wipe up any spillage. A small scoop coater may be held in one hand, but wider ones must be supported at both ends to keep them steady

when working. To apply the coating, the sharp edge of the trough is brought into contact with the mesh at the bottom of the screen and the trough tilted slightly so that the emulsion just wets it. The coater is now moved up gently and steadily towards the top of the screen without breaking contact between the mesh and the thin edge. The angle of tilt of the coater will have to be adjusted continuously to keep the emulsion level constant above the coating edge. When the coating trough reaches the top, it is tilted back, moved back and forth slightly with a sideways movement to wipe the edge on the mesh to avoid dripping and pulled away gently, breaking contact. The trough is now put aside; the screen removed, flipped around to expose the squeegee side and wedged in place once again. After checking to see if there is sufficient emulsion left in the trough, the operation is repeated on this side. Doing so will force most of the emulsion onto the flat, print side of the mesh as this is where most of the stencil thickness should reside. The squeegee side of the screen should contain just enough emulsion to cover the mesh completely. Performing all these actions should result in a nice, uniform layer of emulsion clinging to the mesh and covering a large rectangular area, leaving a narrow open border all around. The deposit of emulsion may be somewhat thicker along the two sides that were swept by the ends of the coater. A stiff piece of cardboard or plastic card may be used to level these stripes by smoothing off the surplus emulsion into the border areas. The drawing below depicts emulsion coating of a screen in progress.

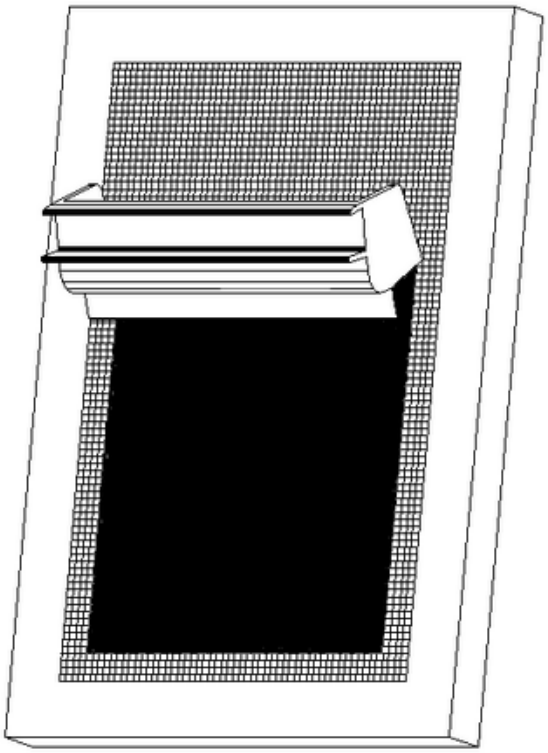

Fig. 11.2 Coating a screen with photosensitive emulsion using a scoop coater (aka emulsion trough)

The emulsion-coated screen is inspected closely to detect any flaws, which if not too big, may be repaired with a small artist's paintbrush. If there are large, uncovered areas, the scoop coater will have to be applied again but this may not give the thin, even coat that is desired. The best way to do the job is to get it right the first time, but it does take some practice to wield the scoop coater with finesse. An expert can hold the screen with one hand and wield the coater with the other to get neat, uniform coatings every time.

The emulsion-coated screen must now be placed in a dark, dust-free environment where it will not be disturbed until perfectly dry. Screens that are exposed and developed before they are completely dry are a cause of major problems because they yield lower quality stencils besides disrupting production by breaking down prematurely. The screen must always be supported by its ends in a horizontal position with the printing side down and squeegee side up when drying. A screen placed in a cupboard or cabinet with forced air circulation will dry faster than it would in still air. If the current of air is warmed by a low powered electric heater, the screen will dry very fast. The danger in using warm air to dry a screen is that the outside dries very fast, trapping the moisture in the middle. The emulsion feels dry to the touch at the surface, while still retaining moisture inside. Time plays a more critical role than temperature when it comes to drying emulsion coatings. A dust filter should be installed at the air inlet. On no account should hot air be directed onto the screen, as this will achieve the same effect as exposing it to UV light but without the selective action of the latter in defining the areas to be hardened. The drawing shows a coated screen kept in the correct position for drying.

Fig. 11.3 An emulsion coated screen must be left to dry in the dark in a horizontal position with the squeegee side facing up.

If the mesh is not really taut, the thickness of the emulsion coating will not be uniform. This is because the lip of the coater will tend to push the mesh at both of its ends more tightly than it pushes against the mesh in the middle. The result will be a stencil that is thicker along the middle and thinner along the two sides. There is no remedy for this problem just as it is the case for all problems arising due to lack of adequate tension in the mesh.

Sometimes it will be necessary to make the stencil quite thick when it is desired to put down a heavy layer of ink on a substrate. In this instance, the procedure is to apply as many coats of emulsion with a scoop coater as are required to build up the thickness, after allowing a drying stage between each successive coat. The extra coats are applied on the substrate side always. It is also possible to apply multiple ‘wet on wet’ coats to build up the thickness but it is more difficult to obtain uniform stencil thickness this way.

The emulsion-coated screen when dry will be ready to be passed on to the next stage where it will be kept in contact with a positive and exposed to ultraviolet light. However, this can be delayed, if necessary, as a prepared screen will retain its photosensitivity for a considerable length of time if stored carefully under controlled conditions. The storage life of freshly coated and dried screens can vary widely from about a week to as long as three months depending on the characteristics of the emulsion used. No two products, even if they are of the same type, will be alike in this respect but the product data sheet will give some indication regarding this aspect. Coated screens that are not going to be exposed right away are put inside black plastic bags, sealed with tape and stored under cool, dry conditions in a dark enclosure.

At the end of the coating operation, any surplus emulsion left in the coater should be transferred with a spatula, preferably into a separate container for re-use. Emulsion that dries hard on the scoop coater is difficult to remove, therefore at the end of work it should be washed thoroughly, wiped dry and stored safely with the plastic edge guard in place. With a little bit of practice, coating emulsion with a trough becomes a straightforward exercise.

Photo stencil materials are nowhere near as sensitive to light as photographic film. Therefore, there is no need to equip an area like a photo lab grade darkroom when working with these materials. Photographic film and papers are sensitive to the full range of the visible spectrum whereas photo stencil materials are susceptible only to visible blue/violet light and invisible UV rays. All work must be carried out in subdued light though, in a room from which direct sunlight has been blocked out. The window curtains must be drawn during daytime and a low wattage incandescent bulb must be used if work is performed at night.

Chapter 12 – Positive Films

Chapter 8 contained a description of the methods by which printing screens could be made using cut film stencils and in *Chapter 9*, an explanation of block out stencils was given. However, the far more popular method of making printing screens today is the photo stencil process. This is based on exposing a special photosensitized material to the action of ultraviolet light, which has the effect of transforming it into a tough and insoluble substance. A practical photo stencil is made by applying a coating of this material onto the mesh and drying it in the dark, followed by exposing it to ultraviolet light passing through a positive film bearing a likeness of the design. The design is represented as dark, opaque areas on the positive film so they would block the transmission of UV light. The clear, open areas on the film would allow the UV rays to pass through and harden the stencil material underneath, rendering it insoluble. After exposure, the stencil is simply washed in water or developed in a chemical solution as appropriate. This has the effect of dissolving and removing the unaltered stencil material that was shielded from UV radiation by the opaque areas of the film, unblocking the mesh openings at these locations. The result is a photo stencil-based printing screen with open areas replicating the design and through which the printing ink will be deposited onto the substrate during the course of printing. The stencil and the positive film should be kept in very close contact while the exposure is taking place to prevent light leakage, thereby ensuring accurate transfer of the design.

From the foregoing brief explanation of the photo stencil process, it will be evident that the positive film plays a crucial role in the preparation of photo stencil screens. All photo stencils are made by exposing them through positives and so the quality of the former is greatly influenced by the quality of the latter. Just as the details in a photograph are dependent on the quality of its negative, so it is with the photo stencil and its positive. Therefore, it is important to learn about the various techniques employed to prepare these image bearing films and the requirements they must fulfill to produce high quality work.

There are several ways to make positives for exposing screens and the simplest of these is the method based on a special product known as masking film. This is a two-layer product, built up of a red or amber colored transparent film supported on a clear, colorless sheet of polyester referred to as the “carrier’. It is possible to see right through the masking film, the material being constructed this way to facilitate the tracing of artwork. The polyester base allows unimpeded passage of all light rays, but the colored layer possesses rather selective light absorption characteristics that effectively block out all ultraviolet and blue color light rays while still permitting a restricted amount of visible light to pass through.

The artwork is placed on a flat, level surface and covered by the sheet of masking film with the colored layer facing up, then taped in place to prevent movement. A sharp stencil cutter is used to incise the upper colored layer of the masking film following the lines of the artwork. Cutting masking film with a stencil cutter is an art that requires a modicum of skill but this can be acquired with some practice. If cut too deeply, the base layer would also be cut and so just enough force must be exerted to cut only the upper layer. After cutting, this layer would be divided into many separate pieces held in place by the tacky adhesive binding them to the carrier. Those pieces of the colored layer corresponding to the non-printing areas are peeled off now. This operation is known as weeding or stripping. The result would be a positive of layered construction comprising a clear base layer onto which are stuck separate pieces of colored UV-opaque film replicating the image and corresponding to the open areas of the photo stencil.

It is also possible to produce positives out of masking film by using a computer-controlled vinyl cutter to incise the outlines of the artwork, but the weeding would still have to be performed by hand. Due to their mechanical construction, masking films are more suitable for dealing with large, blocky designs but they do not lend themselves readily to the reproduction of images containing narrow lines and fine detail. *Rubylith* and *Amberlith* are red and amber colored masking films marketed by the *Ulano Corporation*. They are very popular with screen printers all over the world. *Automask* brand masking films are made by *Autotype Ltd*. These are also available in red and amber colors. Red film is more opaque to UV light than amber film and is preferred when using a vinyl cutter, but amber film is easier to see through and is more appropriate when the image must be traced and cut by hand. The product made from masking film may be regarded as a mechanical positive as the image is formed on it by physical manipulation.

The hand cut stencil film discussed in Chapter 8 and the masking film used for preparing positives have many features in common. Both are translucent products of layered construction that must be cut with a stencil or vinyl cutter. One important point of difference is that in the case of stencil film, material must be weeded from the areas to be printed, whereas with masking film material must be weeded from the non-printing areas! This is shown in Fig. 12.1 below, which must be compared to Fig. 8.2 on page 41.

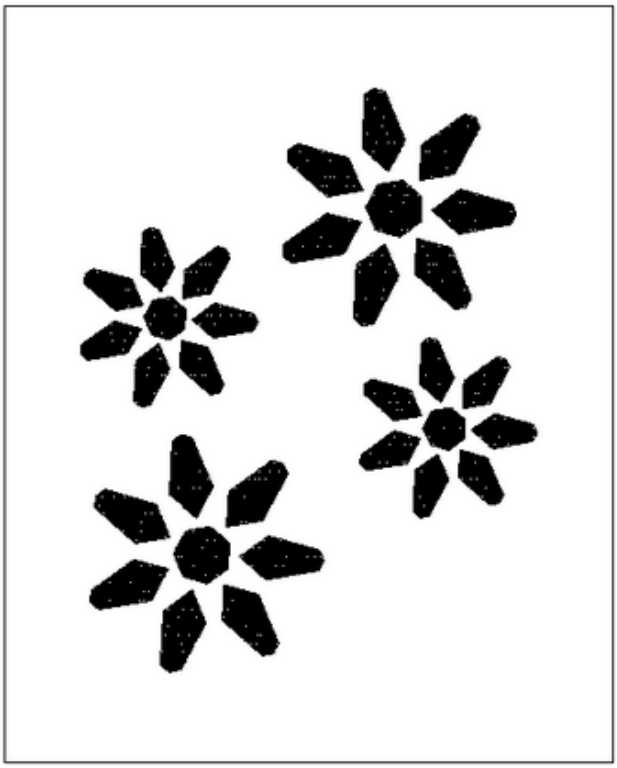

Fig. 12.1 The masking film after stripping off the opaque masking layer from the non-printing areas.

Another point of difference is that the stencil film is stuck permanently onto the screen mesh to form the working stencil whereas the masking film is used to expose photo stencils made of other materials. A masking film that has been cut to shape can be used repeatedly to expose any number of screens.

The most direct way to make a positive is to hand draw the text or design onto a sheet of transparent material with an opaque marking pen. This approach would faithfully recreate on the stencil the deftness of an artistic hand and is thus suitable for producing art prints, freehand drawings and hobby projects. However, there is limited scope for this technique when it comes to producing commercial work, as that is mainly concerned with the reproduction of geometric shapes, logos, existing artwork, letters and numbers.

The simple fact is that it is not possible to produce accurate stencils or positives containing intricate details by resorting to manual or mechanical methods. This is because in all these methods the image formation is based on some kind of mechanical movement. Therefore, printers had to devise more advanced techniques to obtain results that would meet the demands of the commercial marketplace, which is now comprised of customers who want rather elaborate print output.

Inevitably, the next evolutionary step taken to prepare positives was to adopt the photographic approach. High contrast stock popularly known as lithographic film was used, which yielded solid black and perfectly clear areas with hardly any intermediate gray tones. The contrast between the opaque and clear areas was very marked and this was ideal for the purpose. The 'lith' film resembled a photographic negative but carried a positive image, hence was called a photopositive. The artwork was drawn in black ink on white paper and photographed with a process camera. The resulting negative that was smaller than the artwork was then blown up to the required size and used to expose another film yielding a positive print. The term photopositive is sometimes applied loosely to all positives, even if they are made through non-photographic methods.

The production of photopositives based on traditional photographic techniques is a rather cumbersome exercise because of the need for a specially equipped studio and laboratory to capture the image and process the film, in addition to some knowledge of film processing, so this method is now used only rarely for screen printing work. Presently, hardware such as scanners, printers and computers running sophisticated graphics and CAD programs are employed to produce high quality positives. Before delving more deeply into this subject, it is necessary to acquire an understanding of the attributes that positives should possess to ensure the generation of high-quality photo stencils.

The medium employed for making positives may be clear plastic film like cellulose acetate or polyester; translucent white material like tracing paper or vellum may also be used for less demanding work. Vellum is made from rag pulp and is stronger and heavier than tracing paper. Film based materials are more expensive but possess higher UV light transmission characteristics allowing faster exposure. They are also capable of producing higher contrast positives, but the pulp-based products are still popular as they possess other advantages and yield good results at a lower cost.

The matter to be printed could comprise text, design or both and is known as artwork. The positive has to carry an exact likeness of this artwork in the form of a dense black, opaque image. The UV light transmission through the image areas should ideally be 0% but in practice would be about 5% and never more than 8%. The clear or white areas should theoretically possess a light transmission of 100% but again in practice this may fall in the 85 to 95% range. The opacity and transparency of the contrasting areas of the photopositive can be measured and quantified by a device known as a transmission densitometer. Strictly speaking, the readings should be taken using an ultraviolet light source. The minimum density is possessed by the transparent or background areas, which is identified as ***Dmin*** and expressed as a low number with a value of around 0.1. The maximum density is possessed by the opaque or image areas identified as ***Dmax*** and expressed as a higher number such as 3. The difference between ***Dmin*** and ***Dmax***, which represents the dynamic range, should be as great as possible and this value gives

an accurate indication of the contrast. As you may have guessed, this is a logarithmic scale and as such the readings would require some interpretation, but they can be figured out with a little practice.

As noted earlier, the most popular method of making positives today is by putting the ubiquitous computer and the associated technologies to work. This naturally requires some knowledge of computers, printers, graphics applications and so on. With the computer-based approach, the first requirement is to get the subject matter onto the hard disk or SSD where it will be stored as a file in some suitable format. There are many ways to set about this; the artwork could be drawn on white paper and input to the computer by means of a flatbed scanner or digital camera. Images are usually scanned in RGB mode by scanners. Artwork that is already in the form of a digital file such as clip art may be downloaded from the Internet or copied from some other source. The other approach is to generate the artwork on the computer itself using one or more graphics programs. These are generally divided into two broad classes. There are many bitmap (a.k.a. raster) based paint programs like *Paint Shop Pro* and *Painter*. *Windows Paint*, included in the OS itself, has rather limited capabilities. *Adobe Photoshop* and *Corel Photopaint* are basically raster applications with some vector capabilities. There are also vector based drawing programs like *Adobe Illustrator* and *Coreldraw* that can import raster images but not edit them. In addition, computer aided design (CAD) programs may also be used to prepare artwork intended for the generation of positives. CAD files are also in vector format. Two well-known applications are *Autocad* and *Turbocad*. For subject matter consisting of just text, *Microsoft Word* offers a feature known as Word Art that can turn out fancy text. Many other programs too can manipulate text into fancy shapes. Most users routinely employ several applications to get the exact results they want. Raster and vector objects are tricky to combine in the same drawing though, due to fundamental differences in their makeup.

The actual generation of artwork, whether on paper or the computer monitor, calls for appreciable artistic or creative skill on the part of the operator. The orientation of the matter on the positive is the same as that on the original artwork, usually referred to as right reading. Reversed or mirror image positives are specified mainly for preparing certain types of printing plates used by regular printing presses. All contact positives must be made on a 1:1 scale. That is, the size of the image on it will be the size of the image that will be copied on the stencil.

When dealing with images made up of a limited number of colors placed in different areas, it will be necessary to make a separate positive for each color. The smallest areas in the image must be of workable dimensions to put this into practice. The image is opened in a suitable graphics program such as say, *Adobe Photoshop*. Click on **Window** in the menu bar and open the **Color** and **Layers** boxes listed in the drop-down menu. Set the foreground color in the color control box to black by moving the three sliders all the way to the left. The image to be separated will be designated as the **Background** in the **Layers** box. As many additional layers as there are colors in the image should be created by repeatedly pressing the square button at the bottom of this box. The colors are separated by highlighting alternately, the source image layer and the layer that will carry each color in turn, while performing certain other actions. To separate the first color, highlight **Background** on the **Layer**s palette to display that layer on the screen and click the Magic Wand tool on those color areas. The highlighting is done by clicking on the rectangular box to the right of the tiny image. Usually, all the areas covered by a given color will be selected as indicated by the animated dashed line, known as the 'marquee'. The tolerance or range setting of this tool should be adjusted so that the marquee follows the outlines of the colored areas as closely as possible. Now click on Layer 1 on the Layers palette and the highlighting will jump from the Background layer to this layer. You will notice a new layer on the screen that will be blank except for the marquee that

continues to demarcate the areas selected earlier. Click on the Paint Bucket tool on the main toolbar and pick inside this area. This part will be filled in black in Layer 1 but the original color will remain intact on the **Background**. Click on **Select** on the menu bar and press on **Deselect** to remove the marquee that is still on display.

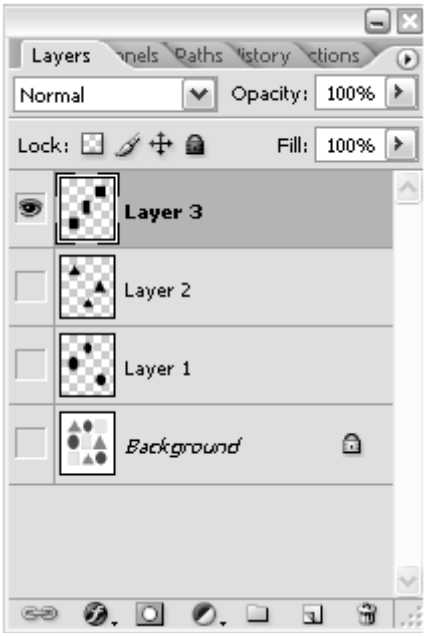

Fig. 12.2 The Layers palette of Photoshop.

To separate the second color, highlight the **Background** again as this is the source layer, click on the Magic Wand tool and pick on the areas to be selected. The marquee will reappear and outline all the areas covered by the second color. Now switch off the **Background** by highlighting Layer 2, click on the Paint Bucket tool and pick these areas to fill them in black. Click on **Deselect** again to clear the marquee. Have only one layer highlighted at a time as otherwise you may lose your way and have to start over from the beginning. Once all the colors have been separated in this fashion, the file may be saved under some format that will preserve the layer information. This can be accomplished quite easily because the **File > Save** dialog box offers the appropriate options, the most popular of which is the .PSD format. The .TIFF format can also store layers. Note that all the colors in the source image would have registered as black in this file but each one would be on a separate layer as indicated in the **Layers** palette box as shown in Fig. 12.3.

Printing the separations is not difficult either and may be carried out by highlighting each layer in turn as before to display it on the screen. On the **Print Dialog** box, the **Output** option should be chosen instead of **Color Management** and the **Registration Marks** box checked.

The colors in an image may be separated into layers using other graphics applications as well but the steps may differ. In *Corel Photopaint* for instance, the layers are referred to and treated as objects. As the Layer menus and commands vary widely from one application to another it is important for the computer operator to acquire proficiency in all the programs being used.

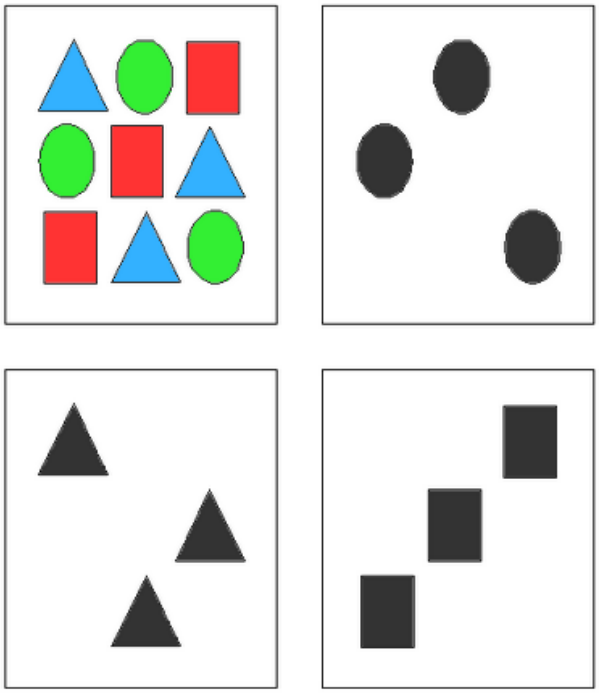

Fig. 12.3 Each color is put into a separate layer and converted to black to achieve maximum opacity.

When many screens have to be prepared for any type of multi-color job, it is necessary to provide registration marks on the positives. When the screens are exposed, these marks will be transferred to the stencils where they will greatly facilitate proper registration when setting up the screens for production. Without proper registration, the different colors will not be deposited in the correct locations resulting in untidy prints. The print dialog box of the graphics program will offer a selection of registration marks and one of these may be chosen. A paper printout of the full image with the registration marks may also prove useful for aligning multiple screens on the baseboard to obtain correct registration.

The images that have been processed as above and stored in the computer may now be used to print out the positives using either laser or inkjet printers. The printers can turn out at low cost as many positives as are required with a few clicks of the mouse. Considering the laser printer first, the printouts may be on vellum or transparent film. The transparent medium intended for use on laser printers is quite different from that meant for use with inkjet printers, hence the products cannot be used interchangeably. Both films are usually made of polyester and treated on one side only with a special coating that is specific to the type of printer. Laser toner adheres poorly to polyester and therefore the films are coated with some resinous material that promotes adhesion between the two. The film is fed into the printer one sheet at a time ensuring that the treated side will contact the print drum. The density control must be turned to the highest setting to get the thickest deposit of toner onto the film.

A laser printout on white paper may appear jet black when examined by reflected light but this is not the case with film that has to work with transmitted light. It is indeed possible to view objects right through the toner deposited areas on film. It follows therefore, that during exposure, the areas blocked out by toner would allow some light to pass through, thereby causing the emulsion in those areas to harden at least partially. One way to get a blacker deposit of toner is to pass the film through the printer again so that the image is printed twice. Modern laser printers have very accurate paper feed mechanisms and if the

film is placed in the identical position on the feed tray, there should not be any misregistration. This trick will work for simple designs but not for highly detailed or halftone images.

Another approach is to treat the printout with a liquid, also available in aerosol form, made specially for darkening laser printed images. This product is called toner darkener or image brightener and is sold under various trade names such as Laser Buddy, Ultra Black, Posi Black etc. Applying this liquid or spray causes the toner particles to soften somewhat and fuse together, transforming the granular and porous deposit into a cohesive coating. Though a visual examination may not reveal any significant increase in opacity, the toner's ability to block UV light will be much improved. This product is also used by the makers of lithographic printing plates for the same purpose. If used in liquid form, it is applied sparingly with a brush and allowed to dry. It so happens that sometimes products intended for other uses also have the effect of rendering laser printed output opaquer, though they may not perform as well and tend to give variable results. Some examples are clear spray lacquer, artist's spray fixative and hair spray. Positives could also be printed on vellum, which is a special variety of tracing paper made for laser printers. Toner adheres very well to this material but as it provides a lower contrast than film, the printout should be subjected to a darkening treatment as above.

Images with flat color areas could be produced equally well with the aid of inkjet printers. Inkjet film with a special gelatin-like coating on one side is used for this purpose. Inkjet printers have more paper type and print quality settings than laser printers and therefore some experimentation will be necessary to figure out the right combination that would yield the most dense and opaque printouts. There is a setting for transparencies in the paper type list but the heavy matt paper setting often yields more dense images that are better suited for positives. Intermediate quality settings will usually put more ink on the medium than lower or higher quality settings. Then there is the ink density control itself, usually hidden away somewhere in the print dialog box, that could be used to great effect. The opacity of pigment-based inks is often higher than that of dye-based inks. What matters more than the type of ink though, is its origin. The printer manufacturer's ink will always possess greater opacity than ink manufactured by third parties, but it will be more expensive. The inkjet film should be fed into the printer the correct side up and one sheet at a time.

If you really have difficulty in getting your inkjet printer and ink to produce opaque blacks with a high ***Dmax*** value, then you could try stacking two identical positives to expose the screen. Tape them together after superimposing the matter perfectly and increase the exposure time to compensate for the higher ***Dmin*** value obtained now. There would be a slight drop in edge definition that may not matter for non-critical work. Anyway, you should adopt this approach only as a last resort.

Standard desktop printers cannot handle any medium wider than 8½". Wide format printers are therefore rather more useful for screen printing work. It is possible to turn out larger positives on a standard printer by tiling the images, a feature available on all newer models. It may be accessed on the printer setup dialog box where it is referred to as poster printing. The printouts need to be trimmed neatly and joined together with clear tape to make workable positives in the case of simple, blocky matter.

Very high-quality positives are usually prepared by using imagesetters. These are sophisticated and expensive equipment found in service bureaus engaged in the production of printing plates for the printing, publishing and packaging industries. An imagesetter exposes photographic film by scanning it with a computer-controlled laser beam. The film will require chemical development by a wet process in a darkroom. Some imagesetters employ thermal film that can be used right out of the imagesetter as it is a

dry process, working on the same principle as thermal paper. However, photographic film yields a much more durable image as it will never fade. With either type, the output will be very sharp and display high contrast. Service bureaus will undertake orders for positives if the digital image files are made available to them. Imagesetters are devices that can generate very high-resolution output. By using them, it is possible to produce complex and large size positives.

There is a way to accomplish the same thing that a positive does but without employing any medium such as vellum or film. In this method, which is limited in popularity, ink is deposited directly onto the surface of the emulsion coating on the screen. This technique is known as ‘direct to screen inkjet’. A specially constructed large, flatbed inkjet plotter that can accommodate work pieces with a thickness of up to two inches is used to print the image directly onto the screen with opaque ink. Avoiding the use of a separate medium to carry the image delivers greater accuracy. This purpose-built device is rather expensive, so that might work against its widespread adoption.

When printing the positives, always remember to get an identical printout on white paper. In the case of separations, print out the composite image with the registration marks. The matter on the paper could come in handy for registering the screens later.

As a positive can be used repeatedly to expose many screens it would be wise to store it carefully in a safe place until you are quite certain it will never again be needed!

Chapter 13 – Exposure and Washout

Certain wavelengths of light possess the ability to initiate and sustain various kinds of chemical reactions in susceptible substances. The most active wavelengths, as far as screen printers are concerned, occupy the 340 to 440 nanometer band of the electromagnetic spectrum and are often referred to as actinic rays. In comparison, the visible light spectrum ranges from about 400 to 750 nanometers in wavelength. One nanometer is equal to one billionth of a meter and is abbreviated 'nm'. Wavelengths shorter than 400 nm are invisible to the human eye and fall within the ultraviolet (UV) band that extends down to about 100 nm. Thus, it will be clear that the major portion of actinic light is present in the invisible UV band and a smaller portion present in the visible spectrum. The visible portions of this band are perceived as violet and blue by the eye. Screen printers generally overlook some of these finer points and use the terms actinic light and UV light interchangeably because the differences are mostly of theoretical interest and of little practical consequence on the shop floor. It may be noted that sunlight contains virtually all wavelengths of light and is very rich in the rays that promote chemical reactions. UV radiation is often referred to as 'black light' as it is not directly visible. A chart depicting a small part of the electromagnetic spectrum is presented below, but keep in mind that the cutoff points are not so sharply defined in real life.

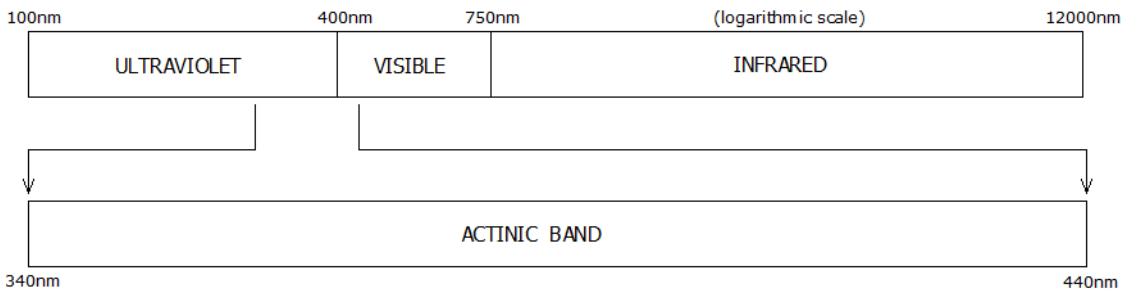

Fig. 13.1 A major portion of the 'actinic' rays lie inside the UV band and a smaller part inside the visible band of the electromagnetic spectrum.

A freshly coated and dried screen is exposed by keeping the printed or masked side of the right reading positive in intimate contact with the emulsion on the flat side of the screen frame and exposing it to the action of actinic light rays that pass through the clear or white areas. When the exposure is complete, the emulsion coating is developed by washing out with water or in some cases, a developing solution. All parts of the emulsion that were under the open regions of the positive would have been converted into a tough and durable material by the action of the actinic light rays and adhere tenaciously to the mesh. The other portions of the emulsion coating that were shielded from the action of the actinic light by the opaque areas of the positive would remain in an uncured state and hence easily dissolve and wash out, opening up the mesh in those areas. The screen is blotted carefully with tissue and dried well. The result would be a photo stencil with open and closed areas bearing an exact likeness of the image carried on the positive.

For the purposes of commercial production, it is essential to use some suitable apparatus or equipment for exposing screens on a routine basis and in an efficient manner to obtain consistent results. The function of the apparatus is to hold the sensitized screen and positive securely in very close contact and in the correct position with respect to the light source. The more advanced equipment will have a light source built into it but it is also possible to make use of a simple exposing box with an external light source for this purpose.

The exposing box is usually made of wood and be of a size sufficient to accommodate the largest screen in use. The box should be seven or eight inches deep internally and fitted with a clear glass front not less than a quarter inch in thickness. The box is equipped with a removable back cover with provision for securing it firmly in place. Two handles are fixed on opposite sides of the box to facilitate lifting and moving it around. Polyurethane foam blocks of differing thicknesses cut to the required sizes are kept handy. To expose a screen, the exposing box is first placed on a table with the open end up and the inner face of the glass wiped clean. The inked side of the positive is placed in contact with the emulsion coating on the flat side of the screen frame, centered correctly and secured in place with two short strips of clear adhesive tape at opposite ends to prevent any relative movement. The screen frame is now placed on the glass inside the exposing box and its rear surface is covered with a piece of black cloth that has been cut to the size of the internal well. The cloth is put there to prevent light that has passed through the emulsion once from being reflected and exposing it again as this will result in a fuzzy stencil. A piece of polyurethane foam cut to the internal dimensions of the screen frame and somewhat thicker than its depth is placed in it. Additional sheets of foam cut to the size of the exposing box are stuffed inside and pressed by forcing down the cover, which is then secured in place. All this should result in forcing the positive and emulsion layer into intimate contact as they are both squeezed together tightly between the glass front and the foam blocks. The exposing box is now turned over and the outside face of the glass wiped clean. All these operations should of course be performed in subdued light to avoid fogging the emulsion coating. The glass front of the box is kept covered with a large square of thick cardboard until the screen is ready to be exposed. The setup is depicted in the illustration below.

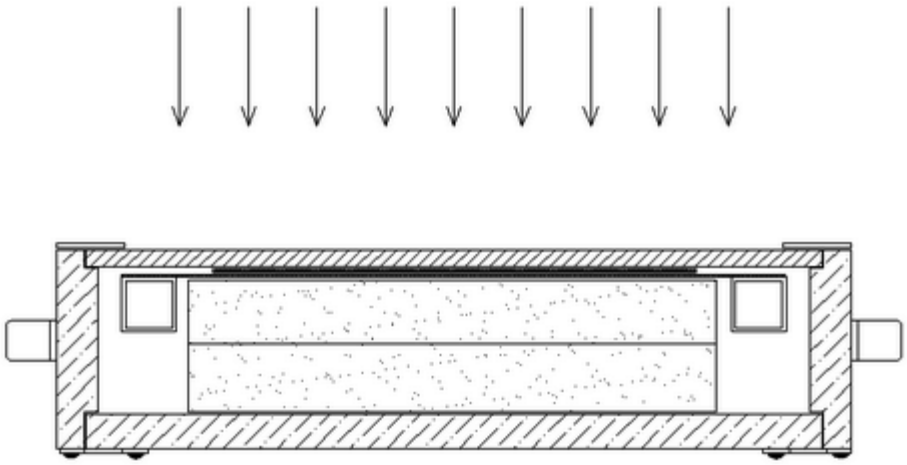

Fig. 13.2 An emulsion coated screen set up for sunlight exposure in an exposing box. The positive is sandwiched between the screen and the glass top.

On a bright, sunny and preferably cloudless day, it is possible to obtain very good results by utilizing sunlight to conduct the exposure. The assembled exposing box is taken out into the sunlight with its top covered by a cardboard sheet and placed on a level and stable surface. A watch or preferably stopwatch is used to time the exposure. Most photo emulsions of the diazo type would require no more than about fifteen minutes to be exposed fully under bright tropical sunlight. Photopolymer emulsions are fast exposing and would require only about four minutes or so. The stopwatch is started as the cardboard cover is removed and stopped when it is replaced in position. The exposing box may now be brought indoors, the screen taken out and the positive removed. The screen is subjected to a gentle water spray to remove the emulsion from unexposed

areas. A high-pressure jet of water must never be used for washing out stencils. The emulsion would still be in a soft condition at this stage but after drying fully will harden and turn into a durable material.

Sunlight has its advantages and disadvantages when used for this purpose. It is free and does not involve any capital or running costs. On a good day, the exposure times can be fast as sunlight is very bright and rich in actinic rays. The light intensity will be uniform over the entire area of the screen. Undercutting of stencils cannot occur because the rays of light emitted by the sun are parallel. The last statement is true if there are no clouds to scatter and diffuse the light and the screen is placed perpendicular to the rays. The use of sunlight conserves energy and it is non-polluting as well.

There are disadvantages too associated with choosing sunlight for the purpose of exposing screens. One of these is the restricted time span available per day for conducting sunlight exposure even during fine weather because for good results, the sun cannot be too far away from the overhead position. Exposure opportunities may not be available during bad weather, which may extend for several days at a stretch during certain seasons. Moreover, estimation of exposure can be difficult due to sudden variations in light intensity caused by the constant passage of clouds.

Since busy screen printers cannot be expected to depend on the vagaries of sunlight, artificial sources of light have become the norm nowadays as they allow perfect control to be exercised over the exposure parameters, thereby facilitating the attainment of predictable and repeatable results. Exposures can be conveniently carried out at any time of the day or night. Several types of lamps are in use such as mercury vapor lamps, UV fluorescent tubes and metal halide bulbs, all of which emit light rich in ultraviolet rays. Mercury vapor lamps are available in both low pressure and high-pressure forms. The former type does not require a choke (i.e., ballast) but the latter type does. UV light, by definition, is not visible to the human eye. Nevertheless, it can cause eye discomfort and staring directly at a UV light source could lead to blindness. Prolonged exposure may also result in “sunburn” of the skin. Therefore, caution must be exercised when working with UV lamps.

A low or high-pressure mercury vapor lamp hung from above may be used to expose screens set up inside the exposing box as described earlier. The exposing box is kept on a table directly under the lamp and the glass front covered with a board. All mercury vapor lamps need to warm up and reach their normal working temperature to emit the full actinic output. Therefore, the cardboard cover must be removed to commence exposure only when the lamp has warmed up fully. In addition, this type of bulb cannot be powered on immediately after switching off, as it needs to cool down before restarting. It is therefore important to understand the characteristics of these lamps if the exposing operation is to be executed smoothly. Some arrangement should be worked out for raising and lowering the bulb easily to adjust its height to suit the different sizes of screens in use.

It is quite feasible to expose screens under an overhead indoor light source without using a specially made exposing box. The inner face of the screen is supported on foam blocks with the positive taped onto its lower surface which will now be facing up. A heavy glass sheet is placed on the screen, forcing the positive into reasonably good contact with the emulsion coating. The lamp is then switched on for the required duration to expose the screen. The screen can be washed out now and good results obtained if the timing of the exposure has been judged correctly. Fig. 13.3 shows this very simple setup.

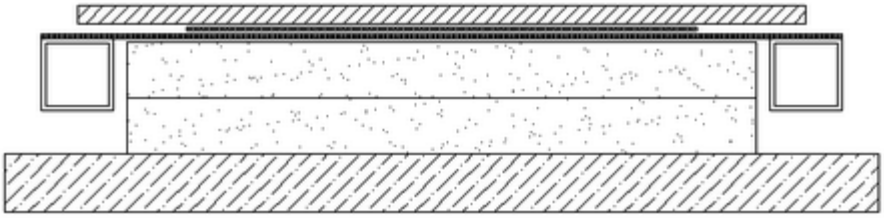

Fig. 13.3 Screens can be exposed even without the aid of an exposing box by weighing down the assembly with a heavy sheet of glass.

The perpendicular distance between the center of the screen and the lamp is set approximately equal to one and a half times the diagonal dimension of the rectangular stencil area. This is done to ensure that the right balance is struck between uniform light intensity over the stencil area and a reasonably short exposure time. Increasing the distance will lead to a more even distribution of light but prolongs the exposure time too much because the intensity of illumination of a surface is inversely proportional to the square of its distance from the light source. It will thus be seen that doubling the distance will quadruple the required exposure time.

The actual exposure times required in the case of artificial light sources depend on a number of factors such as the type of lamp, its power rating in watts, the size of the screen, its distance from the light source, the type of emulsion, the thickness of the stencil and the demands of the subject matter. As there are so many variables to contend with, the beginning screen printer will have to figure out the exposure times on his own and arrive at an estimate based on the properties of the equipment and materials used. The label or product data sheet of the emulsion may provide some guidance on this. To give an example, a time of 20 minutes may be deemed adequate for exposing a thin coating of diazo emulsion using a 160W MV lamp positioned 20 inches away, when dealing with a bold, blocky design.

A simple way to determine the time of exposure accurately is to make a step wedge test. This is based on a series of five exposures in which the estimated time is fixed as the middle exposure. Four additional exposures are made, two above and two below it, separated by equal intervals. For example, if the correct exposure has been estimated as 15 minutes, further exposures are made for 9, 12, 18 and 21 minutes. The same positive that will be used to expose the working screen is used with the test screen. The emulsion is coated lengthwise as a two-inch-wide strip with a brush, on a test screen fitted with the same type of mesh. After drying, the positive is taped to it and the screen put inside the exposing box. A series of five incremental exposures is made as follows. The first exposure is made over the full length of the emulsion strip for a period of 9 minutes. At the end of this period a long, 4-inch-wide strip of cardboard is placed on the glass top of the exposing box covering about one-fifth of the emulsion along its length. At the end of 3 minutes, the cardboard is moved further to cover two-fifths of the length of the emulsion-coated area. After another 3 minutes, the cardboard is moved to cover three-fifths of the emulsion strip and 3 minutes later to cover four-fifths of its length. The lamp is switched off 3 minutes later. This procedure would result in the emulsion-coated area being divided into five blocks, the first one exposed for 9 minutes, the second one for 12 minutes and the third, fourth and fifth blocks exposed for 15, 18 and 21 minutes, respectively. The time intervals may be more or less than three minutes, depending on the illumination level and the sensitivity of the emulsion.

After washing out and drying the test screen, the details appearing on it are compared to that on the positive. An actual print made with ink is checked against the positive to

determine the exposure timing that gave the best results. If two adjacent blocks seem to produce equally good prints, the one that received the longer exposure should be taken as the correct one as it would prove more durable. This way of zeroing in on the correct timing is known as the incremental exposure method as different parts of the emulsion are subjected to progressively greater levels of exposure.

Specially designed test film positives are marketed for determining exposure times more accurately. They are really needed only for making stencils containing small text, halftones or fine lines. The *Autotype* Exposure Calculator is one example. It is a variable density positive film comprising five columns of grey of differing light transmission values. Each column also contains text, halftone samples and a resolution target. A single exposure of a stencil through the test film positive would yield five rectangular patches of emulsion, each cured to a different degree by the action of the five graded filters that allow varying amounts of light to pass through. At the top of each gray band is marked an exposure factor that must be applied to make the necessary correction.

When using the *Autotype* calculator on a test coating of emulsion, it is first necessary to make a rough estimate of the exposure that would be needed by studying the various factors and referring to the data sheet of the emulsion. Once this is determined, the figure is doubled and used as the test exposure time. The exposure may be made now by keeping the test film positive in tight contact with the emulsion under the light source for the prescribed duration. After washing out and drying thoroughly the resulting photo stencil is inspected carefully and the column that provides the best detail is identified. The actual exposure time that was used is multiplied by the decimal factor appearing at the top of this column to arrive at the precise exposure needed for this emulsion under the prevailing lighting conditions and setup. The instructions provided with the test film positive should also be referred to, so that the best results may be obtained.

A source of light that is very popular for making photo stencils is the fluorescent tube that is used in arrays of 4, 5, 6 or 8 lamps for this purpose. Two-foot or four-foot lamps may be used, depending on the size of the screens. The lamps need to be spaced closely to ensure uniform light intensity with each lamp wired to its own ballast and starter but connected to a common switch. The lamps are housed in a wooden compartment with a thick glass top on which the photopositive and screen are placed during exposure. The spacing between the glass top and the lamps is about 2½ inches. The inner surfaces of the enclosure should be painted white to provide a bright and even distribution of light. Many printers use “Tropical Daylight” type bulbs and obtain good results, but UV fluorescent lamps enable much faster exposure, thereby saving valuable time. To complicate matters though, there is more than one type of UV fluorescent tube. The germicidal lamps used for illuminating aquaria and for creating sterile work areas in laboratories are designed to emit maximum output in the 250 nm band, which is far removed from the actinic range. Therefore, ensure that the bulbs you purchase can produce a strong output within the 340 to 440 nm band. All UV lamps are much more costly than regular lamps. The drawing below depicts the design of an exposing unit fitted with fluorescent tubes.

An exposing box such as this greatly facilitates the preparation of photo stencils quickly and easily. As always, the side of the positive on which the image is recorded is kept in contact with the flat side of the coated screen and secured with clear adhesive tape. The screen is then placed on the clean glass surface of the light box with the positive in between. A piece of black cloth is used to cover the inside face of the coated mesh to prevent ‘bounce back’ of light as that would cause fuzzy stencils. A block of foam cut to fit the well of the screen snugly and of sufficient thickness is pressed into it so that it projects comfortably above it.

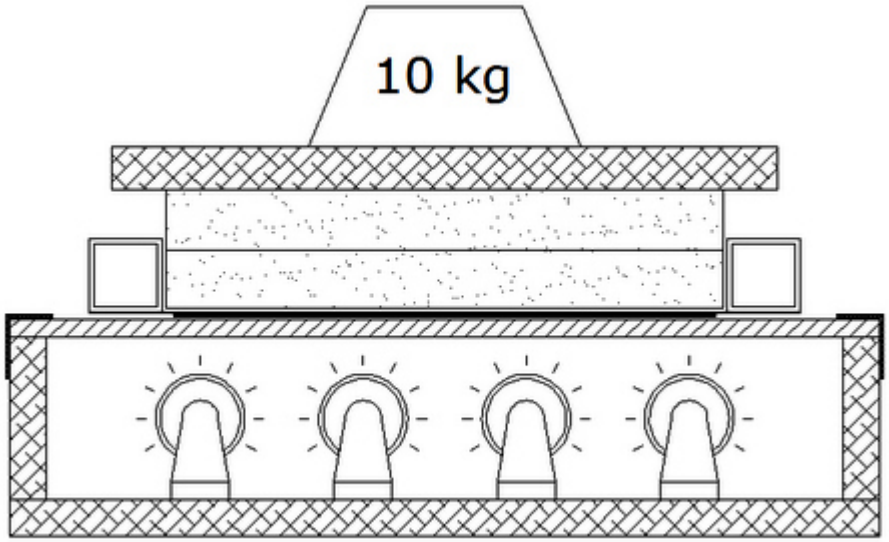

Fig. 13.4 A box with a bank of fluorescent lamps can be used for exposing screens to be used for low and medium detail work.

If necessary, use more than one block of foam. A rectangular plywood board of about the same size as the screen frame is kept on the raised surface of the foam and weighted down with heavy objects to force the emulsion coated mesh, photopositive and the glass top into tight contact with each other. The strength of the glass sheet must be considered when placing the weights! Exposure is accomplished by simply switching on the fluorescent lamps and switching them off when the estimated time has elapsed. The timing should preferably be carried out with the aid of a stopwatch. The exposed screen may then be washed and dried in the usual manner to yield a finished photo stencil.

When exposing photo stencils, the presence of dust particles or lint can prove troublesome at times. The screen, positive and glass top of the exposing unit tend to attract tiny particles due to the prevalence of static electricity on their surfaces. Any dust that is caught in the path of the exposing light as it passes through the assembly will tend to cause pinholes or weak spots in the photo stencil, causing it to break down long before it reaches the end of its projected service life. Therefore, both sides of the screen, positive and glass must be wiped lightly with an anti-static cloth to get rid of all dust before they are pressed into contact for exposure. Anti-static cloth is slightly smaller than a napkin and is made especially for this purpose. It works by exercising a greater attraction for the dust than the surfaces to be cleaned but must be kept perfectly dry to work effectively. The anti-static duster can be re-used several times before it loses its effectiveness.

Speaking of exposure, it is necessary to understand and appreciate an important difference between the geometries of the light rays emitted by a mercury vapor lamp and a bank of fluorescent lamps, respectively. The former constitutes a point source of light as all of the rays falling on the screen emanate from a small, localized spot. This is not so in the case of the latter. A bank of fluorescent tubes backed by a reflective white surface constitutes a light source spread over a large front. The differences in the geometry of the light rays confer an advantage and a disadvantage to each of these light sources. The light from a mercury vapor bulb varies in intensity over the surface of a screen with the central part positioned directly below receiving more exposure than the four corners that are further away. Fluorescent lamps on the other hand are capable of providing uniform illumination as they cover a large area that often extends beyond the stencil. For this

reason, a screen exposed under fluorescent lamps receives more uniform exposure across its surface than one placed under a point source of light.

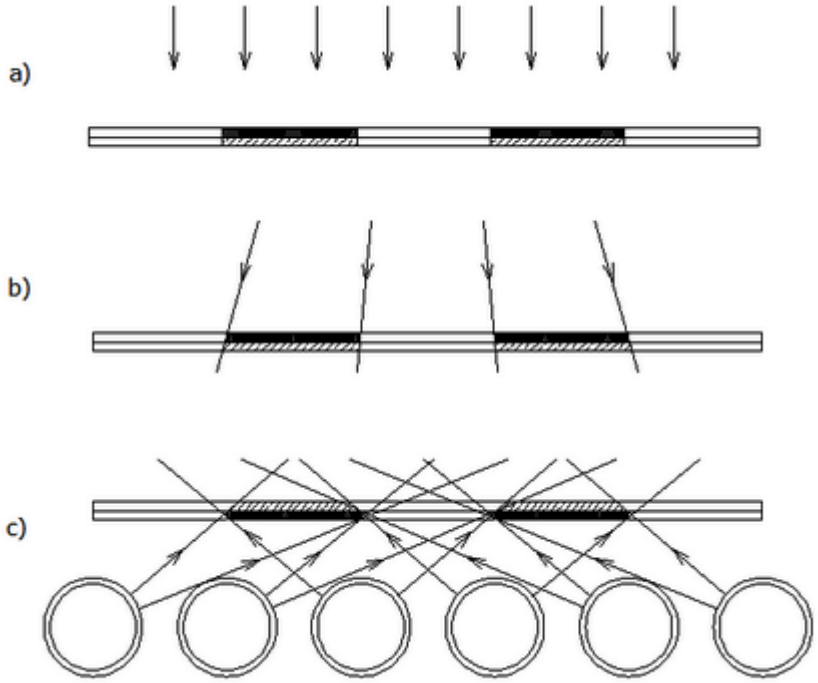

Fig. 13.5

a) There is no undercutting with the parallel rays of sunlight.
b) There is minimal undercutting by the rays of a point source of light.
c) There is heavy undercutting by light rays emanating from a broad front.

Where the mercury vapor lamp scores an advantage in performance over the bank of fluorescent lamps is in eliminating an undesirable phenomenon known as undercutting that tends to erode the quality of an image as it is being transferred from the positive to the emulsion coating. Undercutting occurs when rays of light strike and pass through the same spot on a positive from a multitude of different angles, the phenomenon becoming more pronounced as the angles become shallower. This is exactly what occurs when exposure is carried out under a bank of fluorescent lamps, giving rise to a great deal of undercutting. In the case of point sources of light, despite the rays being slightly divergent, undercutting is much less pronounced because they strike any given target area through a quite narrow range of angles. The drawings above trace the paths of light rays emitted by various sources as they pass through the assembled work pieces. Undercutting is not an issue when dealing with bold and blocky subjects but can pose major problems during the production of printing screens containing half tones, fine lines and intricate detail.

If more than one mercury vapor bulb is used to speed up exposure, the setup ceases to behave as a point source of light, with the result that undercutting will increase. The same thing happens if a large reflector is used to capture and direct more light at the subject because the point source is transformed into a broad diffuse source. Any reflector used behind a ‘point source’ of light should be designed correctly and focused properly to minimize divergence of the beam of light.

The only way to prevent undercutting totally is to resort to a parallel beam of light, which cannot be derived from a point source by any ready means, especially if the area to be

covered is large. Direct sunlight when not diffused by clouds provides a parallel beam that fully eliminates undercutting. The problem is that sunlight cannot be switched on and off to suit the convenience of the screen printer and even when present is unlikely to be consistent.

Screen printers often turn the undercutting phenomenon to their own advantage when it suits them. Sometimes images made up of contiguous patches of different colors may bleed into each other when printed on a porous substrate. It is possible to eliminate this tendency for the colors from adjacent areas to mingle, if each color area can be shrunk slightly in size to leave a small gap between them. This can be accomplished quite simply by placing a clear acetate or polyester sheet between the positive and the screen while exposing each color separation. If the exposure is carried out using fluorescent lamps, the undercutting is increased by the light passing under the edges of the image areas before striking the emulsion, due to the thickness of the clear film. This would give rise to minute gaps between adjacent patches of color that would just get filled in by the spreading inks. This technique is described as ‘choking’.

Specially designed and constructed exposing equipment is available for the use of professional and commercial screen printers. These units are very sophisticated and rather expensive. They usually comprise a high wattage metal halide lamp with blower for cooling, a hinged vacuum frame with rubber blanket powered by a vacuum pump, thick glass top, shutter, light integrator, timer etc. These are all built into a sturdy metal enclosure usually supported on castors, with the monitoring and control panel in front.

In the metal halide lamp, a heavy current passes from one electrode to another through an intensely hot vapor in the form of a powerful and very luminous arc. The electrodes are sealed inside a quartz capsule containing metal halide compounds and gases under pressure. The quartz capsule is in turn sealed inside an outer glass envelope. This is not the same thing as a quartz halogen bulb that uses a hot metal filament to emit light. Metal halide bulbs come in ratings of up to 7000 watts and emit a bluish white light very rich in the UV wavelengths. The bulb operates at a very high temperature and pressure, necessitating a powerful blower to prevent the glass from softening and deforming badly. The bulb is pressurized as it leaves the factory, and the pressure increases even more when it is powered on. Metal halide bulbs can prove very dangerous because if they explode during operation, very hot materials will be ejected from it in all directions at high velocity. Therefore, the operating instructions that accompany the exposure unit and the bulb must be studied with care and abided by strictly.

The exposing unit may incorporate a shutter to cut off the light until the bulb warms up to working temperature. The shutter also comes in useful when several screens are queued up for exposure as it can be opened and closed any number of times conveniently as switching the power supply on and off repeatedly can be stressful for the bulb and the associated circuitry. A bulb that is switched off needs to cool down a little before it can be restarted, and the shutter helps to avoid this kind of delay too. Some exposing units that use ‘quick start’ MH lamps may not be equipped with shutters.

A thick sheet of glass forms the horizontal worktop of the exposure unit. This is sometimes but not always made of tempered glass. Great care must be taken to see that the surface of the glass is not scratched when screens are placed on or removed from it. Scratch marks on the glass will invariably cast tiny shadows on the stencil being exposed, leaving latent impressions in it. The result is that more emulsion will wash off from these areas of the stencil during rinsing and washout, causing weaknesses, which result in premature failure while in service. It may not always be practicable to repair these weak spots by touching up with block out.

The vacuum frame forms an important part of the exposing unit. This is similar in construction to a screen frame but will have to be of a size sufficient to accommodate the largest screen in use with about four inches of clearance on every side. It is hinged to the rear edge of the exposing unit so that it can swing up and down to uncover or cover the glass top. A flexible and highly elastic rubber blanket, usually made of *Neoprene*, is attached to the upper face of the vacuum frame covering that side entirely, while its lower face that is in contact with the glass is lined with a soft rubber gasket around the periphery to provide an airtight seal. During use the screen with the photopositive taped to its flat side is placed on the glass top and the vacuum frame lowered to envelope the screen fully. The vacuum pump is switched on to evacuate all air trapped in the space between the glass top and the rubber blanket. A hose connects the pump to the enclosed space through holes that pass through the vacuum frame. The reduced pressure causes the rubber blanket to be drawn inwards towards the glass top and press down tightly against it, squeezing the emulsion coated mesh, the positive and the glass into intimate contact due to a pressure of about 14 pounds per square inch acting on it. As the atmospheric pressure acts equally on both sides of the glass top, it is not subjected to any stress. The blanket can stretch to a considerable extent to conform to the profile of the screen frame as *Neoprene* is a very resilient elastomer. Incidentally, the material is always pigmented black to prevent ‘bounce back’ of light.

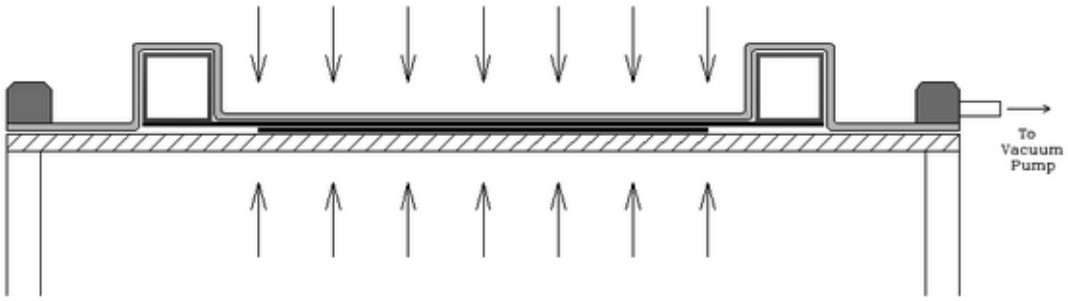

Fig. 13.6 Atmospheric pressure forces the positive and the emulsion coated mesh into tight contact between the flexible rubber blanket and the glass top of the exposing unit.

For a given size of exposing unit, the drawdown time is dependent on the capacity of the vacuum pump. Some units have a vacuum ‘reservoir’ to ‘store’ the vacuum to enable rapid drawdown. Pockets of air may sometimes become trapped under the blanket and if this happens in the region where the exposure is going to take place then that would result in fuzzy stencils caused by imperfect contact between the layers. Air pockets may be prevented by noting the places where they occur and pressing down on the blanket at those spots by hand immediately after switching on the vacuum pump. Another way is to lay a porous (i.e. loosely woven) cord around the stencil area and lead one end close to a vacuum intake opening. Some blankets have a finely textured grid pattern on the lower surface to allow air to escape, without becoming trapped in pockets.

A light integrator is usually provided as standard equipment on the exposure unit. This device enables precise exposures to be made as it measures the actinic energy falling on the screen. The settings required for each class of work are obtained by conducting a few trial exposures. Adjustments can be made easily through the control panel. Using a light integrator is a better way of determining the exposure than timing with a stopwatch, as the latter approach does not consider variations in light intensity caused by such factors as ageing of the bulb or power fluctuations. A timer is a standard fitting on the exposure unit. This can be useful because with a 5000 watt metal halide bulb and a fast

photopolymer emulsion applied as a thin coating, exposure times may fall within the 15 to 30 second range!

As far as the beginner is concerned, the most practical light sources are mercury vapor bulbs and UV fluorescent tubes. As noted earlier, it is more convenient to position the former above the screen and the latter below it. Quartz halogen bulbs are not suitable at all for this work, as they emit a yellowish white light quite deficient in the actinic band. Moreover, only a few bulbs of this type serve as point sources because most of them are equipped with long, straight filaments.

Xenon bulbs, noted for their use in cinemas as excellent sources of projection illumination, are also occasionally used to expose stencils because of their bright, bluish white light. However, metal halide bulbs are the ones commonly installed in commercial exposing units. This is because the range of wavelengths to which most photosensitive emulsions are susceptible, happens to coincide with the spectral output of metal halide lamps more closely. Both these bulb types are known as High Intensity Discharge (HID) lamps. These are low voltage, high current devices usually started by a high voltage pulse generated by an igniter circuit. Their spectral outputs are tailored by varying the mix of gases and volatile compounds contained within the arc chamber. The pressure inside these bulbs, even when not burning, is greater than that inside a truck tire and so they should be handled with the respect they deserve.

A major difference between filament lamps and discharge lamps lies in their spectral outputs. The former type emits a continuous spectrum of light while the latter are noted for their line spectra. Metal filaments emit a smooth, unbroken spectrum of light containing all wavelengths within a given band. In marked contrast, discharge lamps have spectra with very sharply defined valleys and peaks that vary according to the lamp type and design. The spectral emissivity graphs of discharge lamps show comb like patterns. Exposing times will be shorter than that estimated if the light output of a lamp happens to coincide with the actinic susceptibility of an emulsion exactly. Conversely, if there is a bad mismatch between the two, the time taken for optimum exposure will be much longer than anticipated. This is one of the reasons for making test exposures.

Whatever type of bulb is used for exposing, its light output will keep on diminishing steadily with usage. Allowance must be made for this by increasing the exposure times correspondingly. The great advantage of a light integrator is that it accurately measures the total light energy falling on the stencil without simply determining exposure on the basis of elapsed time. The UV output of lamps tends to drop at a faster rate than the visible output. Therefore, it would be advisable to replace bulbs at specified intervals as they will keep on working long after their efficiency has dropped drastically, in which case exposure times would be prolonged unnecessarily. This would also lead to an increase in electricity consumption.

At one time carbon arc lamps were used for exposing screens but the fumes and spatter generated by the consumable electrodes and the need for a motor driven feed mechanism for the positive electrode eventually rendered them unpopular. As a matter of interest, the spectral output of the arc was adjusted by filling the core of the carbon rod with specific metallic compounds during manufacture.

Once the exposure has been made, by whatever means, the screen is washed in plain water. It is leaned against a vertical surface resting on its narrow side inside a groove on a support so that it remains stable. A firm spray of water is directed on it by means of an adjustable spray head. The washing operation should start from the bottom and work its way upwards gradually. The screen should be turned over and the other side washed likewise. The washing should be repeated on both sides covering the entire coated area.

As the emulsion would still be in a soft condition, great care must be taken to treat it gently. The water pressure may be increased a little to remove any emulsion that proves difficult to wash off from the open areas, but a high-pressure jet must not be employed for this purpose. Rubbing gently with a fingertip will also help to remove partially cured emulsion without damaging the hardened portions. If the stencil feels too soft or slimy at this stage, it means the exposure has been inadequate. A final rinsing off carried out on both sides should be followed by blotting the resulting photo stencil with absorbent tissue.

The screen is now placed in a drying cabinet or cupboard and given a chance to dry completely. Thereafter, it is inspected carefully to locate any pinholes or other defects. A most convenient aid to carrying out touch up work would be a simple light box. This can be of wooden construction, fitted with two or four short fluorescent lamps under an opal glass top. Four or six LED bulbs could be used instead, arranged in a rectangular grid pattern. Any flaws in a stencil may be easily spotted if the screen is kept on top of the backlit glass. Do not use any UV bulbs in the inspection light box.

If defects are present, these are filled in by touching up with the same emulsion or a suitable block out by working from the substrate side. A fine artist's paintbrush is used to obtain a smooth finish. If emulsion is used to do the touching up, the stencil must be dried in a dark enclosure and exposed again to harden it, but the duration is not critical. A general rule concerning exposure is that, when in doubt, it is always better to err on the side of overexposure than underexposure. An overexposed stencil may yield less than perfect prints in a consistent manner but will not disintegrate, causing severe disruption in the middle of production the way an underexposed stencil is wont to do. Remember that incomplete drying before exposure and underexposure are the two leading causes of premature stencil failure.

Whichever light source is used for exposing a screen, it is unlikely that the procedure will be carried on long enough to harden the emulsion under the clear areas of the positive to the maximum possible extent. It may be impractical to do so if the difference between the ***Dmin*** and the ***Dmax*** of the positive is not sufficiently wide. Keeping the screen against the light for too long may cause the emulsion under the opaque areas also to harden somewhat, rendering the washing out process rather difficult. For this reason, screens may not always be given a chance to receive the maximum theoretical exposure they require to ensure complete hardening during the exposing cycle. Therefore, it is strongly recommended that all exposed screens be subjected to a dose of post exposure just to make sure they are fully cured and hardened before being passed on to the production floor. Fortunately, post exposure is a very simple and easy operation to perform because any light source with an actinic content will serve well and the period of exposure is not critical so long as it does not drop below a minimum level. The sun is the best source of light for this purpose in tropical countries. After ensuring the screen is completely dry, it is placed on a raised platform out in the sun in a protected place where birds, stray animals and humans cannot disturb it. On a bright day, a quarter of an hour should suffice.

When the need arises for an extra-large printing screen for some special project, it may not be practical to print out or expose using a regular 1:1 scale photopositive. In this case, the screen may be exposed using the direct projection method. This is a non-contact technique that makes use of a reduced size photopositive mounted in a powerful slide projector using the right type of bulb. The beam is focused on the emulsion-coated screen placed in a darkened room for a prescribed period. This approach, however, is only suitable for producing low and medium resolution work intended for general display.

The production of halftone positives is the subject of the next chapter but a few words about the exposure of halftone positives would not be out of place here, it is hoped.

The exposing of halftone stencils must be carried out with great care, as the quality of prints made from them is very much dependent on the care with which this operation is performed. As always, the screen should be perfectly dry when it is ready for exposure. The amount of light energy received by the stencil must be within very narrow limits when transferring halftone matter from a positive and it is easy to demonstrate this by carrying out a series of exposures on a simple test pattern that you can generate using your favorite graphics application. The pattern is made up of a series of alternating black and white stripes, all of them one mm wide by 20 mm high. A photopositive is prepared next, bearing three sets of this pattern. A screen is exposed through this positive with varying exposure times applied to each set of stripes. This can be accomplished by sliding a strip of cardboard at intervals to cover the patterns successively as needed during exposure in the manner described earlier.

A print made from this screen should appear as shown in Fig. 13.7 if you had timed the exposure correctly for the middle pattern. The black stripes would be slightly wider than the white spaces on the print at the left that was made from the underexposed pattern and so this print will appear darker than the original when viewed from a distance. The black stripes and the white spaces would be of equal width on the print at the middle that was obtained from the correctly exposed pattern. This print will appear normal and resemble the original pattern very closely. The black stripes would be slightly narrower than the white spaces on the print at the right made from the overexposed pattern and so this print will appear lighter than the original when viewed from a distance.

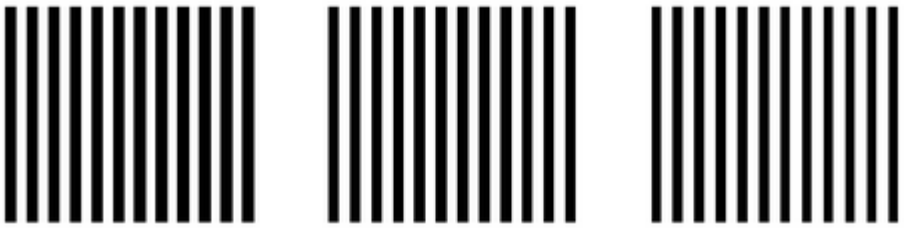

Fig. 13.7

Print made from underexposed stencil	Print made from correctly exposed stencil	Print made from overexposed stencil

If the effects of overexposure and underexposure can be so noticeable in the case of 1mm wide stripes, then imagine what effect they might have on the tiny dots with which halftone images are built up?

Halftone stencils are the most susceptible to undercutting. For this reason, only point sources of light such as the mercury vapor or a metal halide lamp prove suitable for exposing these stencils. A bank of UV fluorescent lamps forms a wall of light that floods the positive and screen from all directions and at low angles too, so that the smaller dots fail to cast any shadows in the emulsion directly behind them. This is likely to cause severe dot loss even in a slightly underexposed stencil, rendering fluorescent lamps unsuitable for halftone work. In theory, sunlight with its parallel rays should serve well for exposing halftone stencils but the practical difficulties in estimating the required exposure accurately work against it in this demanding application.

Sometimes heat tends to build up on the glass top of exposing boxes during prolonged exposing sessions. This has the potential to cause two problems. Firstly, it can cook the emulsion under the opaque areas of the positive too, hardening same and making wash out difficult. Buildup of heat could also cause inkjet positives to stick to the emulsion on

the screen. This is caused by softening of the ink receptive coating present on all inkjet films. Sticking will also damage the positive so that it cannot be reused. This aspect of the problem may be solved by dusting some talcum powder sparingly onto the printed side of the positive, lightly rubbing over its full area and wiping off the surplus. Powder should not be applied directly to the emulsion coating on the screen. Cooling the glass top with a fan may help to some extent but a better solution would be to employ a fast-exposing emulsion.

Finally, here is a tip for prolonging the useful life of emulsion coated screens that you have created for use with water-based inks. What you must do is apply a special treatment to the screen before passing it on to the production department. This treatment hardens and renders the emulsion wear resistant, extending its service life and making possible very long production runs that can yield 50,000 or more prints. Coat both sides of the stencil liberally with a solution of water-resistant hardener and allow it to dry slowly. Application of the WR Hardener toughens the stencil by reacting with the emulsion and rendering it capable of withstanding the rigors of very long production runs. By way of comparison, a stencil without this treatment may begin to disintegrate after producing only about 15,000 or 20,000 prints. It is difficult to give exact figures due to the number of variables involved. The hardening operation can only be justified for very long production runs and on stencils that have turned out perfectly after exposing and washing out because screens subjected to this treatment cannot be reclaimed later!

Chapter 14 – Halftone Positives

So far only the techniques used for producing positives of images with spot or flat color areas have been discussed. Line art images are also of the same type but comprise only one color, normally black. The preparation of positives required for making stencils used to print continuous tone images though, is a rather more complicated affair. It calls for an understanding of standard printing processes and techniques. Continuous tone images are called that because there are no sharp gradations of tone in them but a gradual transition of shades from jet black to snow white as in a full range black and white photograph. There may be more than 500 shades of gray in such a photograph. Black and white are also counted as shades of gray by the graphics artist. A regular printing press that uses a single black ink on white paper would need to depend on some special technique to be able to print out several shades of gray. Fortunately, a technique known as screening allows printing presses to reproduce multiple shades of gray using only black ink on a white background. The quality, however, is compromised somewhat because the picture is printed using a rather limited number of distinct shades, numbering around 50 or so because a press cannot reproduce as many shades of gray as there are to be found in a photograph. What screening does is to break up the image into a grid pattern made up of tiny cells that are usually square. Each cell is made up of a white area and a black area. The proportions of these areas can vary greatly and will correspond to the intensity of the shade on the original image at the location occupied by the cell. The cells in the lighter image areas have more white background showing through and the cells in the darker image areas have more ink on them. The cells when grouped together and viewed from a distance may appear a lighter or darker shade of gray, depending on the ink coverage within the cells.

This technique of breaking up a continuous tone image into a regular array of dots of varying sizes is known as halftone screening and it continues to remain an indispensable technology to the printing industry even today. In the not-too-distant past, special photographic processes were employed to screen the image. Nowadays screening is performed almost exclusively on computers running graphics software. An important property of halftone screening is the line count as this value exerts a profound influence on the appearance and quality of the printed matter. Line count is usually stated in terms of ‘lines per inch’, sometimes abbreviated to ‘lines/in’ or simply as ‘lpi’. The line count expresses the resolution, which is the property that determines the fineness of detail that can be reproduced in the image. The line count refers to the number of rows in the grid of dots that would fit inside a width of one inch. For the normal run of screen-printed work, the practical limit of resolution is about 100 lpi for paper and 50 lpi for cloth. Different types of halftone screens are provided in the software to control the shape of the dots, which can be square, round, elliptical, diamond shaped and so on. Seemingly put in there to make life more interesting and challenging to printers, they do help to fine tune the appearance of the printed output by influencing the way the halftone dots increase in size.

Unfortunately, it is not possible to print out halftone images with just any printer and obtain satisfactory or predictable results. Standard desktop printers will pretend to oblige but will not deliver the results you expect. They will not show any error messages warning the user of their inability to service the request. Instead, the printer adopts an obliging attitude and prints out something that does not in any way reflect the instructions entered in the print dialog box of the application. The reason for this is that the standard desktop printer does not have the special hardware item known as a Raster Image Processor built into it. The purpose of the RIP hardware is to enable the printer to interpret complicated data sent to it by the graphics application. The encoded data stream will contain precise instructions on dot placement to enable the printer to accurately reproduce the fine halftone dots, complex font outlines and other page layout operations. Therefore, it is

necessary to ensure that any printer used for press-related work such as small font generation or halftone screening has built into it a Raster Image Processor to decode this data. The most popular RIP solution is *Adobe PostScript,* which is usually implemented in hardware form in output devices such as laser printers and imagesetters. Therefore, if you intend to produce halftone positives you need to equip your shop with a *PostScript 3* laser printer. *PostScript 3* is the latest version of the most popular Page Description Language in use today for Desk Top Publishing and pre-press work.

Very high-quality halftone positives are usually prepared by using imagesetters. These are sophisticated and expensive equipment found in service bureaus engaged in the production of printing plates for the printing, publishing and packaging industries. An imagesetter exposes photographic film by scanning it with a computer-controlled laser beam. The film will require chemical development by a wet process in a darkroom. Some imagesetters employ thermal film that can be used right out of the imagesetter as it is a dry process, working on the same principle as thermal paper. Photographic film yields a much more durable image though. With either type, the output will be very sharp and display high contrast. Service bureaus will undertake orders for positives if the digital image files are made available to them. Imagesetters can generate high-resolution output and are controlled by the *Postscript 3* printer control language or something that yields similar output such as an *Emerald* controller. By using these, it is possible to produce complex and large size halftone positives.

If you are interested in exploring half toning, you could start off by printing on paper a few experimental screened images of a grayscale picture. Before proceeding, keep this in mind! When a continuous tone raster image is converted into a halftone by screening, complex vector information is also generated which is converted into *PostScript* data. This can be stored in an EPS file as this format is able to store both vector and bitmap data present in an image. This data is intended to be processed by a printer with the *PostScript* RIP built into it. The page information encoded in this data cannot be and will not be displayed correctly on the screen of your monitor and neither will the image be printed out accurately on a standard desktop printer. What is displayed on the monitor will be a rasterized preview with a somewhat jagged appearance and the image that is printed out will not contain any more detail than the one on the monitor! If you did use a *PostScript* printer and everything worked out all right the result should be a perfectly printed page with a far higher resolution than the preview image appearing on the monitor.

Incidentally, all graphics hardware on computers and almost all graphics software applications can work with only 256 shades per channel. A grayscale image can display only 256 shades of gray on the monitor and a desktop printer can print out even less. Image files too contain information for only 256 shades per channel. In a grayscale image, black is assigned a value of 0 and white a value of 255, this being the highest number that can be expressed by eight bits in the binary system.

To print out a halftone positive from a grayscale image, open it in Photoshop. Click **File > Print with Preview….** If the **More Options** button is visible, click that and choose **Output** in the **Output/Color Management** selection box. Click on the **Screen** button to open the **Halftone Screen** dialog box and uncheck the **Use Printer's Default Screen** checkbox. It is here that the halftone parameters such as the **Frequency** in lines per inch, the screen **Angle** in degrees and the dot **Shape** are entered in the input fields. The screen angle is invariably set at 45° when printing single color images. The dot shape is not very critical, and you can choose round or square until you have gained further experience. The trickiest part is setting the line frequency correctly as the number that is entered in this field may not bear any definite relationship to the actual line count that is obtained on the printout. There are numerous reasons for this, one of which is that the printer's resolution

is also involved in the process, and this can vary widely. Therefore, the value of this parameter must be arrived at by trial and error. The only sure way to verify the line count on the printout is to place a precision ruler parallel to a row of dots and start counting across a width of one inch.

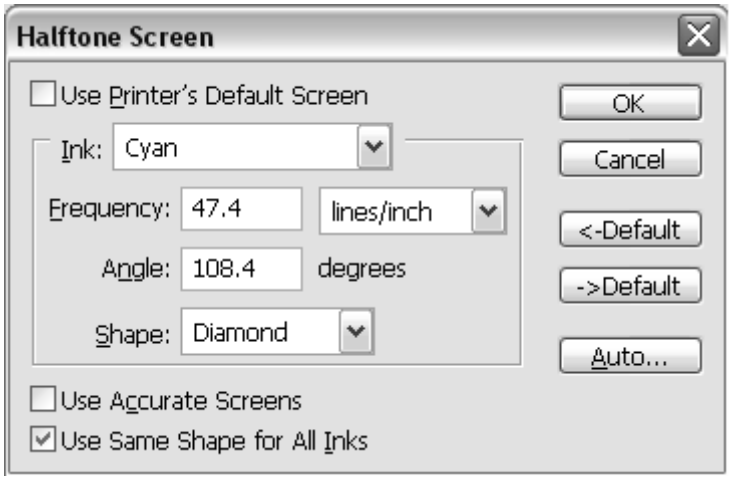

Fig. 14.1 The halftone screen settings dialog box of Photoshop

Of course, before doing all this, a picture or graphic has to be chosen first and this is something that must be done with care. The picture must look good to start with. It needs to be bright, clear and sharp with good definition and sufficient detail. A large picture is far preferable to a small one. If necessary, it must be cropped so that the main object of interest is sized and centered properly.

The resolution at which the halftone image should be printed on the substrate must be determined with care. Screen printers use values in the range of 40 to 100 lines per inch for the normal run of work. Rather low resolutions, say from 40 to 60 lpi are preferred for printing on textiles due to their coarse and porous nature. Wood, thin plastic sheet, cardboard and paper are usually printed at up to 85 lpi. Metal, glass and rigid plastics with smooth surfaces may be printed at resolutions of up to 110 lpi. A resolution appropriate to the nature of the substrate and the demand of the work must be arrived at. When doing this, it is also important to ensure that the resolution of the digital image that serves as the source material is adequate for the purpose. After all, technical common sense dictates that a high quality image cannot be derived from a low quality one, though some enhancement may be possible; but this is achieved more by tricking the eye than by adding extra information to the image.

The general rule is that the resolution of the digital image, expressed in terms of pixels per inch (ppi) should approximately be from one and one half to double the resolution of the image to be printed, expressed in lines per inch (lpi). For example, an image that is to be printed at a resolution of 80 lpi should ideally be derived from a digital image with a resolution of about 120 to 160 pixels per inch. If the ratio of the picture elements between the two media falls below 1:1.5, the quality of the printed output will suffer. If the ratio is greater than 1:2, the image processing time when printing is increased but the extra data is discarded.

This point should be borne in mind when scanning images that are to be printed out later, because redundant picture information slows down the computer without delivering better results. Down-sampled copies of digital photographs should also be stored separately to

enable faster processing of images intended for printing positives. To do this, the amount of digital data must be related to the physical dimensions of the output, and this involves nothing more than simple arithmetic. The total pixel count needed to print an image is arrived at by multiplying the width at which it will be printed by the desired line count (lpi) and doubling the result. For example, if you wish to print an image with a width of eight inches at a resolution of 75 lines per inch, a pixel count of 1200 would give the best results; a figure of 1050 would give acceptable results but you should not go below 900.

E.g. 8 x 75 x 2 = 1200 (Max) and 8 x 75 x 1.5 = 900 (Min)

Another reason for staying within the above limits is that the results obtained by screening would be more predictable. If there is excessive disparity between the resolutions of the source image and the printed image, the latter may not process as expected. Obtaining the desired results when printing out halftone dots can be tricky for the beginner.

All things considered, the most convenient and reliable way to obtain halftone positives is to get a print service bureau (i.e., printing plate & block maker) to do the job for you. They have at their command high-tech equipment and possess considerable expertise in this type of work. Either the grayscale image file or a sharp paper image suitable for scanning should be provided to them together with the required specifications of the positive such as the output size, line count, dot shape, screen angle and registration marks, etc. They may suggest changes to your specifications as they will know certain things that you may not know. You should also inform them of the intended use so that the image would be orientated correctly. It should be right reading with the emulsion side facing up. As the positive will be output from an image setter, it will be very sharp, possess a high contrast and will conform to the specifications very closely, facilitating the production of high-quality printing screens. It will also save you much time and worry. This will become obvious when you attempt to prepare halftone positives of process color separations, which we shall discuss now.

Sooner or later the urge to try your hand and luck at printing full color, continuous tone images will become irresistible. But the fact is that, doing halftone printing by using screens can be a technically challenging undertaking. To do this it will be necessary to carry out process color separations and prepare the requisite halftone positives first. This work could be farmed out to the service bureau for professional looking results as it calls for high-tech equipment and specialized knowledge. For one thing a *PostScript 3* output device would be needed to accomplish the task. However, for those who are ready and equipped to prepare the positives on their own, the procedure will be described here. But before that, a brief explanation of the conventional full color printing process would not be out of place as it would help you to gain some understanding of the basic principles involved.

In a regular printing press, color images are formed by means of what is known as the four-color CMYK process. Four halftone printing plates are used, one for each color. The four inks used are cyan, magenta, yellow and black. The K in CMYK refers to black, which is called the Key. This technique attempts to reproduce the entire gamut of colors present in a picture or photograph by mixing these hues in differing proportions. The press cannot of course reproduce perfectly every color that can be perceived by the human eye, using the extremely limited palette of four colors, but despite this it does a rather creditable job mainly because of the high degree of refinement attained by this process after several decades of continuous development. The inks are deposited on the paper sequentially in variously configured printing presses. There may be provision for drying or setting the ink after each stage.

Four-color process printing can be accomplished by means of screens but at lower output resolutions and slower speeds compared to conventional printing presses. Four halftone screens are used in place of the halftone printing plates. The inks need to be laid out one after the other with brief, intermediate drying stages. CMYK ink sets formulated for use on different types of surfaces can be procured from screen printing supply houses.

To carry out color separation on a full color, continuous tone image, it should be opened in any capable graphics application such as say, *Adobe Photoshop*, *Adobe Illustrator*, *CorelDraw* or *Corel Photopaint* and edited. In *Photoshop*, all adjustments that need to be made to the image can be carried out by clicking the **Image** button on the menu bar, followed by clicking **Adjustments** on the submenu. If it is desired to apply any special effect this may be accomplished by clicking the **Filter** button on the menu bar and selecting what is wanted on the submenu. It is also possible to alter the image using one or more tools in the toolbar. After editing the image in **RGB** mode, it must be set to **CMYK** mode by clicking **Image > Mode > CMYK**.

Let us first view the separations to see what they look like. Open the **Channels** palette, which can be accessed by clicking on **Window** on the menu bar. This will dock at the right side of the screen. Five small preview images will be visible in this box. The top preview will depict the original full color image that is open on the screen. The four previews below will display the color separated cyan, magenta, yellow and black images, in descending order. The separated colors are converted to black to achieve the maximum contrast possible that is so necessary for all pre-press work. Clicking on the box to the right of the cyan preview will display the cyan separation on the main window.

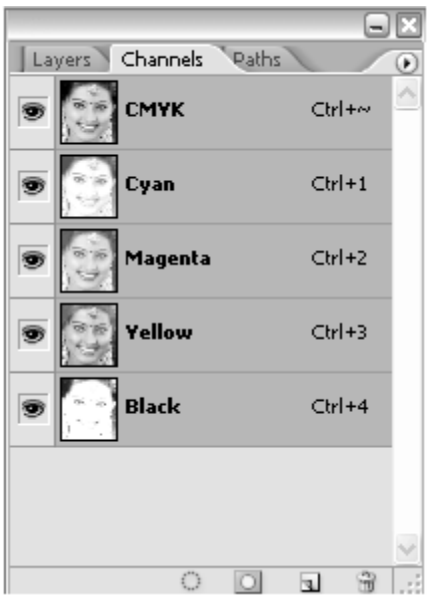

Fig. 14.2 The channels palette of Photoshop displaying the separations.

Clicking thus on the box to the right of each preview in turn will display that color separation on the screen at the original size. The yellow separation will appear very dark because it has been converted to black but when printed out with yellow ink, which is very light, it will be reproduced correctly.

There is an even easier way to view color separations in *Photoshop*. Simply press Ctrl + 1 to display the cyan separation. Pressing Ctrl + 2, Ctrl + 3 and Ctrl + 4 in turn will display

the magenta, yellow and black separations in succession. Press Ctrl + ~ to revert to the original full color image. If you forgot to convert to CMYK, you will see the red, green and blue components of the RGB content. Fig. 14.2 shows the **Channels** palette. The size of the preview images can be set to small, medium or large.

When four color process printing must be performed, whether by means of printing plates or screens, the colors need to be separated, so halftone screening is applied to each color. The normal practice is to combine both operations and execute them from the print dialog box. To do this, proceed as follows. With the source image displayed on the screen, click **File > Print with Preview….** The main Print dialog box will appear. Click the **Page Setup…** button at the top right, then choose the paper size and orientation in the box that pops up and click OK. Set the position and output size of the image to match the paper in the main Print dialog box. The window at the middle left should read **Output**. Click on the **Screen** button to bring up the **Halftone Screen** dialog box and fill in the fields according to your preferences. The **Frequency** may be set in lines/in or lines/cm. This is the most critical and important setting of all because it requires your personal judgment, which is based on the requirements of the screen print job you have lined up. The **Angle** should be set differently for each color of ink by clicking on the down arrow to the right of the **Ink** selection box. Photoshop offers certain default screen angle settings that are already entered in the boxes and by using them you could save yourself much trouble as these are tried and tested values. The dot **Shape** is also set by clicking on the down arrow to the right of this box. What really determines the shape to be chosen is the nature of the substrate and this is explained in a later chapter. Don't forget to add the registration marks which can be done easily by checking the appropriate box. The printer's hardware settings must be set from the printer driver's dialog box but all the software settings must be made from the software application's print dialog box to eliminate conflict. Now click on **Print….** This will bring up another smaller dialog box from which you will be able to access your printer driver's dialog box. Change any settings here if necessary and click **OK**. After a long pause, the printer should spew out the four screened separations with registration marks at the four corners.

Remember to print out a copy of the full image at the same size on white paper, with the registration marks. This will prove useful when the screens need to be aligned and registered.

With some graphics applications the screen frequency, angle and dot shape cannot be entered as the respective input boxes will all be grayed out. This happens if the application is unable to detect that a *PostScript* printer is connected to the computer.

As noted earlier, it is a requirement for four color process printing that the screen angle be set differently for each separation. After decades of experience, the printing industry has settled on a standard set of screen angles for color separations, as indicated below:

Cyan	15°	or	75°
Magenta	75°	or	15°
Yellow	0°	or	90°
Black	45°		

All these angles are set with respect to 0° that is at the 3 O'clock position. The angles for cyan and magenta are interchangeable but must be complementary. Black is usually fixed at 45°. At first glance, setting yellow to 0° or 90° would seem to amount to the same thing, as the rows and columns of the grid are mutually perpendicular. But in fact, a subtle difference should be noticeable, which can only be detected with elliptical or diamond

shaped dots. When set to 0° the long axis of the dots would be horizontally oriented but when set to 90° this axis would be vertically disposed. Either way, it would not make much of a difference to the appearance of the image.

Photoshop and many other graphics applications offer variously modified sets of angles and these could be tried out as they often deliver better results. A properly angled set of screens would lay down the four inks in a fine rosette pattern so that the different colored dots do not fall on identical spots and obscure the colors printed earlier.

Another reason for setting the screen angles differently for each color is to eliminate the distracting and disturbing interference patterns known as Moiré (pronounced **mwar-ay**) which tend to appear when two or more sets of fine repetitive lines or dots are superimposed over one another. Moiré fringes as they are called may easily be observed by holding up and viewing through two layers of polyester mesh. By tilting and shifting one mesh relative to the other, constantly varying interference patterns may be generated. Still and animated moiré effects can also be produced on the computer screen with a program such as *Autocad*. Moiré is an interesting phenomenon that has at least one practical application, but it is quite unwelcome on printed matter. Moiré is more difficult to control on stencils formed on twill weave mesh due to its irregular grid pattern. Therefore, plain weave monofilament mesh should be used for all halftone work to avoid trouble. The accompanying illustration shows Moiré creating mischief.

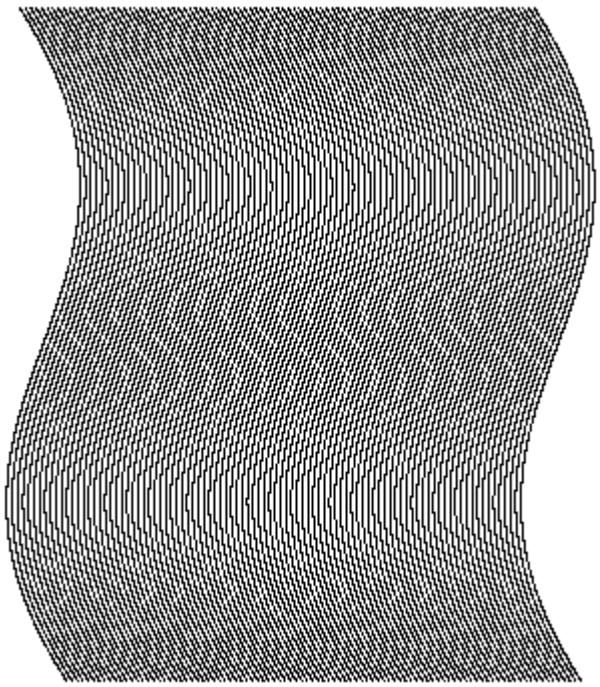

Fig. 14.3 There is only one set of curved lines in this illustration. Despite this Moiré fringes are observed; this happens because the lines interfere with the grid of pixels on the display monitor!

Incidentally, many graphics applications offer a special filter that can transform a continuous tone grayscale or color image to make it look like a halftone. This is merely a simulation and does not involve true screening. The effect is rather coarse but may prove satisfactory for non-critical work when printing directly on paper with a desktop printer. It is unlikely to give acceptable results with screen printing even when a high-quality source

image is used. This feature may be accessed in *Photoshop* by clicking on **Filter > Sketch > Halftone Pattern....** In *Photopaint*, click on **Effects > Color Transform > Halftone....**

A grayscale halftone produced this way may be used to print out a positive directly, after increasing the contrast if necessary. A color halftone image should be separated into the component colors and then used to print out the four positives after making any tonal adjustments as needed.

Even after surmounting the difficulties associated with separating the colors and screening them, further problems may be encountered when working with images composed of halftone dots. Possibly, the biggest of these is the phenomenon of 'dot gain' and 'dot loss'. To understand dot gain and dot loss, refer once again to Fig. 13.7 and the related paragraph in the previous chapter. What was discussed here is the variation in the width of the stripes caused by different levels of exposure when making the stencil. What applies to stripes applies with even greater force and effect to the much smaller dots in a halftone stencil. If overexposed, the dots on the positive that correspond to the open areas will be reproduced as smaller dots on the stencil. This phenomenon is referred to as 'dot loss'. Conversely, if underexposed, the dots on the positive will be reproduced as larger dots on the stencil. This is known as 'dot gain'. Consequently, in overexposed stencils the 'highlight' dots may become too small or disappear altogether. Conversely, in underexposed stencils, the 'shadow' dots will increase in area and eventually merge with other dots to form solid black patches. If halftone images are to display the full tonal range, they must be built up of dots varying in size all the way from 0% to 100% of the cell size in a smooth and progressive manner. In fact, it is not possible to achieve this level of translation even with a perfectly exposed stencil because other factors also play a part in dot formation. Nevertheless, unsatisfactory exposure by itself is enough to cause unacceptable levels of dot loss or dot gain and therefore, great care must be taken to ensure precise exposure during the production of halftone stencils.

Unfortunately, this phenomenon of dot gain and dot loss is again encountered at the printing stage and worse yet, it acts in the same direction. That is, the smaller dots tend to become smaller due to poor ink transfer while the larger dots become bigger and merge into solid areas due to ink spread. The effects of dot gain and dot loss adding up in two stages can result in greatly emphasized highlights and shadows that can affect the tonal range of the original image drastically, always to its detriment. Put simply, the areas showing pure white and pure black increase while the tonal range of the remaining areas becomes narrower.

Fortunately for the printing industry, it is possible to compensate for variations in dot size caused by the many factors that exert influence on all image transfer processes. The remedy lies with the **Levels** and **Curves** controls that are part and parcel of virtually all photo editing applications. What you must do is to darken the highlights and lighten the shadows in inverse proportion to the dot gain and dot loss that you anticipate on any particular job. The only catch is that you need to have some experience so as to be able to exercise good judgment when adjusting these controls. It is possible to make the needed adjustments with either the **Levels** or the **Curves** feature available in the application.

Click **Image > Adjustments > Levels…** in *Photoshop* to open this control box. The two output level sliders found at the bottom will be set to 0 and 255 by default as indicated in the readouts. To lighten the shadows, move the left slider to the right and set the value to between 5 and 30 as appropriate. To darken the highlights, move the slider on the right to the left and set the value to between 225 and 250 by making a rough estimate. By doing this the overall contrast in the image would be diminished somewhat but it will be restored

at least in part when the image is printed out. It is possible to make various other adjustments too in this control box. See Fig. 14.4.

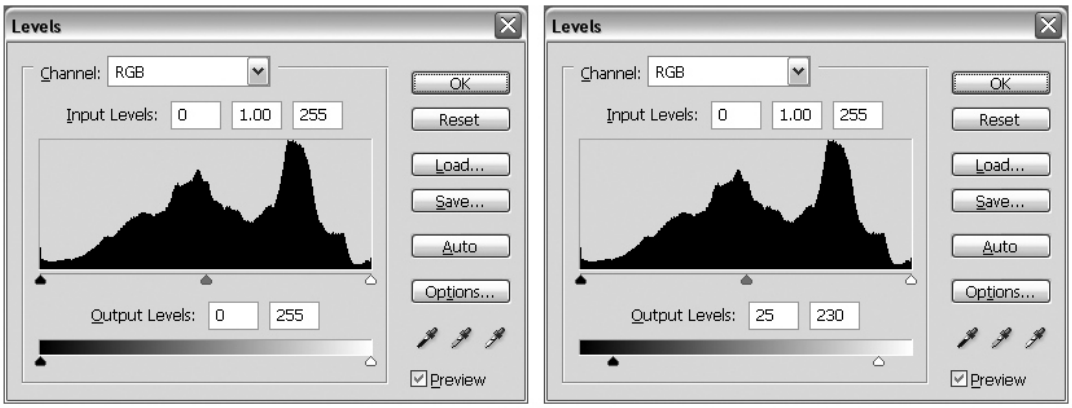

Fig. 14.4 The sliders at either end of the grayscale bar at the bottom are moved inwards to lighten the shadows and darken the highlights respectively.

Alternatively, you can click **Image > Adjustments > Curves…** to bring up another control box and make the adjustments from inside this. The tonal range of the image is represented here as a straight diagonal line. When this box is opened the eyedropper tool appears at the cursor position. As this is moved across the image, the input and output brightness values at different points will be displayed under the graphed area. It is thus possible to assess the brightness values at the deepest shadow areas and also the brightness values at the lightest highlight areas of the image accurately.

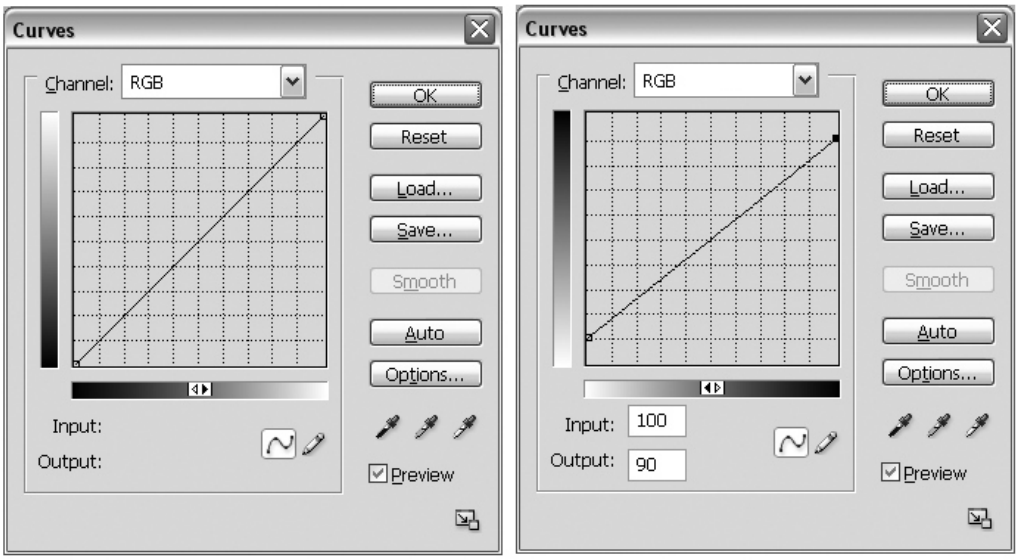

Fig. 14.5 The darkness of the shadows and the lightness of the highlights can both be reduced by adjusting the ends of the line on the graph to control the tonal range of the image.

Now, place the cursor inside the graphed area of the **Curves** control box. Press Alt and click on it to make the grid smaller. When the cursor is moved to the bottom left corner of the graphed box the readout would show 0, when it is moved to the top left corner it would read 255. To lighten the shadows, drag the square dot at the bottom left corner of

this box straight up to a value between 5 and 30 as shown on the readout. To darken the highlights, drag the square dot at the top right corner straight down so that the display reads out a value between 225 and 250. These are the usual ranges within which corrections are made and you rarely need to go beyond them. It is possible to alter the readout to display the brightness values from 0 to 100 by clicking on the double arrow in the middle of the grayscale bar positioned below the graphed area. See Fig. 14.5.

When doing process color work use identical screens and make sure the orientation of the warp and weft yarns are the same in all to obtain tight registration. The use of square dots is not recommended for fine halftone work due to non-linear variations in dot size when passing through the mid gray shades. Make use of dyed mesh for all halftone work to preserve and reproduce the fine dot patterns faithfully.

Matter printed on positives may be either line art or halftone. Line art images are made up of solid black and white areas and halftone images are made up of innumerable black dots on a white background. There is an alternative way to convert a continuous tone image into a series of dots to produce a screened image. This method, known as error diffusion screening, is based entirely on digital image processing technology and has no analog counterpart. There is a fundamental difference between both screening methods. In conventional halftone images, the dots are arranged in rows and columns in a regular grid pattern. The size of the individual dots can vary, at least in theory, from 0% to 100% of the size of the cell. In error diffusion screening, the spacing between the dots can vary widely while all the dots are about the same size. In this type of image, the areas with fewer dots will be lighter in color and the areas with a higher dot density will be darker.

Error diffusion screening is based on the brightness levels of individual pixels and there are several implementations of it, known by various names. It can be chosen instead of halftone screening from the same dialog box. Error diffusion images, however, have a distinctly different look. Photoshop offers just one variety of this screening, but Corel Photopaint offers a wider selection. This type of screening is much simpler to work with, as you do not have to set the line frequency, screen angle or dot shape. You can also output the photopositives with just about any inkjet or laser printer. Moiré is never a problem with four-color printing, obviating the need to rotate screens since interference effects cannot occur as the dots are distributed in a random manner. A further advantage offered by this screening method is that any dot loss or dot gain affects light and dark areas uniformly. Only one aspect requires close attention and that is to relate the resolution (i.e. pixel count) of the digital image to the dimensions of the image to be printed. Just about the only way to get this right is by trial and error. Keep trying until you produce results that look good. Error diffusion screening can provide results comparable to halftone screening when applied to lithographic printing but since dot sizes are much larger in the case of screen printing, it is only possible to achieve artsy effects here, which may be quite deficient in detail.

An important point to be taken into consideration when preparing halftone positives is that good results cannot be achieved by using translucent media. Vellum and tracing paper do not possess a sufficiently low ***Dmin*** value that is so essential when executing critical work like this. For this reason, it would be best to make use of clear polyester or acetate material when producing positives for halftone work.

The use of dyed mesh in screens is strongly recommended when high resolution halftone stencils have to be prepared for demanding work. Some of the light rays that strike clear mesh during exposure pass right through it but the rest are subject to internal reflection resulting in the scattering of light into adjacent areas. This invariably causes some undercutting that leads to dot loss and fuzziness. Dyed mesh, usually orange in color, filters out the entire actinic spectrum, so that any internal reflections and light scatter that

occur will not cause any problem. This will contribute to achieve accurate transfer of the dot pattern onto the stencil. The use of colored mesh calls for an increase in exposure time from about 50 to 150% due to its high light absorption.

Chapter 15 – Indirect Stencil Films

Currently the most popular method of making stencils is by coating the mesh with a photosensitive emulsion, drying and then exposing it. This method is popular because it is simple, straightforward and cheap. Some of the limitations of emulsion-coated stencils manifest themselves when attempting to prepare stencils for high precision work such as those required to produce printed circuit boards, fine halftone work and four-color process printing. Two of the requirements that must be met by such stencils are that they must be very thin and of uniform thickness, conditions that emulsion coated stencils may not be able to meet, depending on the degree of accuracy required. The shortcomings of emulsion-coated stencils also become apparent when very thick stencils need to be prepared for certain specialized applications.

The difficulties associated with forming very thin stencils using liquid emulsion arise due to unevenness in the wet coating that cannot be readily discerned. As the coating dries, some places on the mesh end up with slightly thicker deposits than other places and moreover, shrinkage while drying causes the emulsion to conform to the texture of the mesh. Variations in the thickness of the stencil detract from the uniformity of the ink deposit in a complicated manner, as different sized dots are affected differently. The faint duplication of the mesh pattern on the lower surface of the stencil will not allow it to form a perfect seal on the substrate, leading to a lack of precision in depositing the ink and consequently, poor edge definition.

The preparation of very thick stencils formed entirely of liquid emulsion is also fraught with problems. The customary procedure is to build up the thickness of the stencil by the application of multiple coatings on the substrate side with drying periods in between successive coats. Not only is this a tedious operation, but the variation in thickness tends to build up cumulatively resulting in uneven ink deposits. It has been determined through experience that it is not possible to build up a perfectly flat surface on a printing screen by applying multiple coats of liquid emulsion.

Indirect stencil films were specially developed to address these, and certain other problems connected with the use of liquid mediums for forming stencils. An indirect stencil film, also known as a transfer film, is similar in structure to the hand cut stencil film and masking film discussed in previous chapters. It is also a layered product built up of a thin, transparent carrier sheet of polyester on which is deposited a photosensitive coating of emulsion as a solid film. The carrier sheet may be two or three thousandths of an inch in thickness. The thinner sheets are more suitable for normal work, the thicker ones being preferred for larger work and for work demanding greater dimensional stability so essential for ensuring accurate output and tight registration. The emulsion may be of the diazo or photopolymer type, both marketed in a wide range of thicknesses. These products come in various colors that serve to identify the different types because they possess widely varying characteristics that require appropriate processing. They are supplied as sheets or rolls in lightproof packaging that must be opened in low light conditions and after the required quantity is extracted, re-sealed carefully and stored in a cool, dry, dark environment.

Indirect stencils are exposed first and then adhered to the mesh, which approach confers several advantages to this technique. Exposing these stencils can be a very simple operation as no special apparatus, not even a simple exposing box is needed. The indirect stencil film is cut to size and kept on a wrinkle-free black cloth placed on a smooth, hard surface. It is important to ensure that the polyester carrier sheet is facing up. This is the shinier side as the emulsion layer has a duller appearance. The inked side of the photopositive is placed in contact with the carrier sheet and covered with a sheet of

thick, clear glass. The black cloth, the stencil film and the positive would now be sandwiched together between the wooden board below and the glass sheet above as shown in the accompanying drawing.

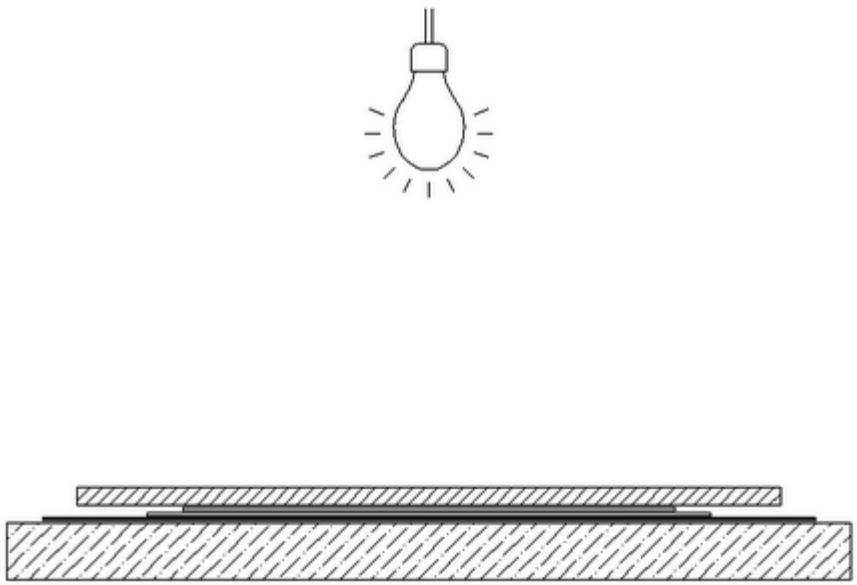

Fig. 15.1 A simple setup for exposing indirect stencils.

An exposing box could also be used as described in Chapter 13. If a commercial exposing unit is being used, the photopositive is laid on the glass with the inked side facing up. The carrier sheet of the film is placed on top in contact with it. It is not necessary to use black cloth, as the vacuum blanket is black. Clear tape must be applied at two places to align the stencil film and the positive correctly and to prevent any accidental shifting. All surfaces concerned must be cleaned with an anti-static cloth when using stencil films because they are more liable to pick up dust and more susceptible to its effects than liquid emulsion. If the exposure is being carried out under a mercury vapor lamp, the glass sheet must be kept covered by a piece of cardboard until the bulb has warmed up. The cardboard is then removed, and the stopwatch is started. The exposure may now be carried out as usual for the required length of time.

Exposed stencil films usually have to be developed by immersion in a dilute hydrogen peroxide solution followed by washing out with warm water and then cold water. Three rectangular aluminum pans are used for this purpose. The film is first kept immersed in a hydrogen peroxide solution of specified strength for a specified period and agitated gently. It is then transferred to a warm water bath at a specified temperature. This bath is then agitated until the image shows up clearly. Next, the film is transferred to the cold water bath to prevent it from softening too much. Information about the strength of the developer, temperature of water bath and duration of immersion will be given in the packaging.

A new generation of stencil films, introduced not too long ago, does not require development in hydrogen peroxide. These may be washed out by spraying directly with cold water onto the emulsion side as the rear surface is sealed by the carrier sheet. After development and washout all unexposed areas would be clear of emulsion and in the exposed areas, the emulsion would remain intact but in a tacky state.

Stencil films need to be mounted on the mesh immediately after washing out, while the emulsion coating is in a soft and gummy state. To do this properly, the film is placed flat

with the emulsion side up on a perfectly smooth surface covered by a large piece of paper without any folds. A clean, freshly degreased screen is centered, then lowered gently and brought firmly into contact with the emulsion layer. Any sliding movement between the two parts should not be permitted, as this would cause the soft emulsion to rub off onto unintended areas of the screen and block the mesh there. To ensure good adhesion, the mesh must embed itself partially into the emulsion. This can be contrived by holding the screen frame firmly in position and drawing a full width squeegee inside it from end to end several times to force the mesh into the soft emulsion layer. This operation requires the services of an assistant to hold the frame immovably. Particular attention must be paid to the corners and the edges. The screen is given some time to dry after which the backing sheet is peeled off carefully. Complete drying is possible only after this. The open rectangular border between the stencil film and the screen frame is sealed by applying a suitable block out with a piece of stiff cardboard or plastic, leveling smoothly and drying it. Once this is done, some post exposure will help to yield a more robust stencil. After taping neatly inside and outside with frame tape, the screen will be ready to print.

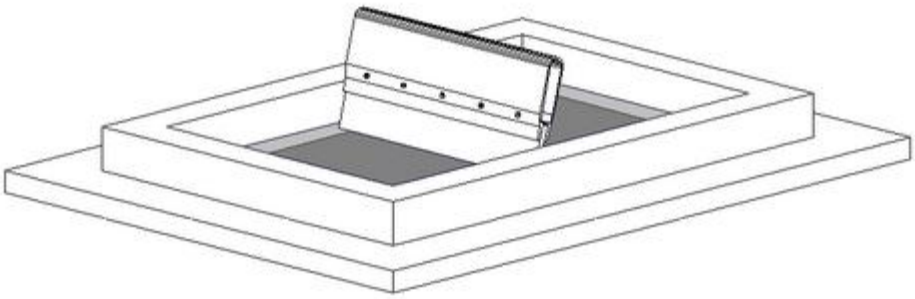

Fig. 15.2 A full width squeegee is drawn firmly along the screen to force the soft emulsion layer on the stencil film partially into the openings of the mesh.

Screen printers choose indirect stencil films primarily for their ability to copy and reproduce high resolution, high-definition images for demanding applications. Resolution means the ability to resolve fine detail such as very closely spaced narrow lines, tiny halftone dots and fine lettering. Definition refers to the ability of the stencil to record and reproduce the edges of straight and curved lines sharply and smoothly without any trace of jaggedness.

Indirect films can measure up to these demands partly due to their flatness and uniformity of thickness but there is also another reason. Light rays that strike the stencil film during exposure pass through it following a straight path and leaving a narrow trail, as there is no mesh to interfere with their passage. When emulsion coated stencils are exposed, the mesh scatters the light by refracting and reflecting the rays. Even the use of dyed mesh will not deliver a clean result. Light scatter causes fuzzy stencils that are incapable of retaining the impression of fine halftone dots.

Indirect stencils are also able to deliver good edge definition. The lower surface of the stencil is smooth, flat and in fact, projects slightly below the mesh, providing a perfect gasket like seal against the print surface. This ensures that the deposit of ink will be confined to the defined areas only and have sharp outlines. In comparison, liquid emulsion dries into a sort of conformal coating that duplicates the texture of the mesh in the case of thin stencils designed for high-resolution work. When the mesh is totally embedded within a thin layer of emulsion, good edge definition cannot be achieved because the crisscrossing yarns break up the continuity of all smooth outlines. When the

outline of an object cuts across the minute hollows on the lower surface of the stencil, ink will seek its way into these depressions during the print stroke, resulting in irregular edges that characterize poor edge definition. See Fig. 15.3.

Fig. 15.3 Examples of good and bad edge definition (magnified view).

The other advantage of indirect stencils is their quick processing time, as they are ready to be exposed right out of the box. Any defects, especially those relating to exposure, can be spotted well in advance, before they are adhered to the screen mesh. This can save a lot of time and trouble. The stencils are available in different formulations and in a range of thicknesses to suit diverse applications. They are available in diazo and photopolymer versions. When the stencils have served their purpose, the screens can be reclaimed quickly with minimal effort because the stencil is attached to only one side of the mesh and the bond can be broken easily.

Among the disadvantages of these stencils is that they are from four to six times as expensive as liquid emulsion stencils. The stencils are also not very durable, and their service life is very short, sometimes amounting to no more than about 3000 prints. In the past, indirect stencil films were intended solely for use with solvent-based inks and were not suitable for use with water-based inks. Lately, indirect stencil films have been introduced for use with water-based inks. Because stencil films are marketed in a pre-sensitized state, they have a limited shelf life, which can be reduced further in tropical countries due to conditions such as high humidity and temperature.

One other matter must be referred to and that is the relationship between the thickness of a stencil film and the mesh count of the screen fabric. Theory indicates and experience confirms that as the thickness of the stencil film increases, the mesh count of the fabric it is mounted on must decrease. The converse is also true. It would make no sense to mount a thin film on a coarse mesh or a thick film on a fine mesh. The general rule is that the higher the resolution at which the matter is to be printed, the thinner the stencil film must be and the higher the mesh count required. This is a point that could be grasped by intuition alone, almost!

Thick stencils can lay down heavy deposits of ink, but they are not very good at printing out fine lines and halftone dots. Thin stencils can only lay down light deposits of ink but are excellent for reproducing fine detail. In fact, the resolution of a stencil is dependent on its thickness to a great extent. A stencil cannot resolve detail finer than its overall thickness and this holds true for all types of stencils.

Due to the high cost and limited durability of stencils, indirect films are usually reserved for very demanding jobs that cannot be executed with liquid emulsion stencils. If a large order for precision work is received, a half dozen or more identical screens must be prepared and kept ready before commencing the production run. Indirect stencil films can prove useful for urgent short run jobs too because a screen can be made very quickly.

Chapter 16 – Direct Stencil Films

Screen printers are never handicapped by a lack of choice because whenever they need to carry out some work relating to their trade, they enjoy the luxury of being able to choose from one of several approaches or methods to perform that task. The situation is no different when it comes to the question of choosing a stencil material. Direct stencil films are one more option on the list. This does not imply that you can just choose any type of stencil for any class of work. You still have to determine which type of stencil is the most appropriate for meeting the demands of the particular print job you intend to carry out.

Direct stencil films are called that because they are exposed after adhering them to the screen unlike indirect stencil films that are exposed off screen and then mounted in place. Currently all direct stencils worthy of note are of the capillary film type. These are also two layer products and as the emulsion is pre-sensitized, they are supplied in lightproof packaging. The film is available in sheet and roll form in popular sizes.

To mount a capillary film on a screen, it is cut to the required size and placed emulsion side up on a smooth, flat surface covered with a large sheet of paper, without folds. A wet screen, fresh from the degreasing rinse is centered and lowered carefully onto it to bring the mesh squarely into contact with the emulsion, without allowing any sideways movement. A full width squeegee is passed lightly across the mesh once or twice on the upper side to bring it into contact with the entire stencil area and wipe away the surplus water that is then mopped up with absorbent material. The screen is flipped over, and the squeegee is passed over lightly on this side too. There is no need to press hard with the squeegee because the emulsion is specially formulated to soften on contact with the film of water and be drawn upwards into the openings of the mesh by capillary action. The softened emulsion will usually penetrate to a depth of around two-thirds of the mesh's thickness over the entire area of contact. The screen may be kept in any position and left to dry in a dark place, after which the carrier layer may be peeled off carefully. The screen must be allowed to dry again, as the freshly uncovered surface is sure to contain some residual moisture. When completely dry, the screen will be ready to be exposed. All of these operations should of course be performed in a low light area.

Another way to mount a direct stencil film is to cut it to the required size and roll it onto a plastic tube with the emulsion side facing out, as shown in the drawing. The screen, wet from the degreasing rinse is wedged at an angle of about 15° from the vertical with the flat side facing outwards. The leading edge of the capillary film is brought into contact with the mesh near the top of the screen, aligned correctly and slowly unrolled without allowing any slack until it lies flat. It is then smoothed out over the surface of the mesh with a couple of strokes of the squeegee. The screen is then flipped over and the squeegee is passed lightly over that side too. This can be accomplished even without a supporting backing surface because the capillary action, which is due to the surface tension of water, is quite strong. After drying, peeling off the carrier and re-drying, the screen will be ready for exposure.

Direct stencils are more durable than indirect stencils as they are embedded deeper into the structure of the mesh and partially locked into it. Indirect stencils are bonded superficially to the mesh and not in any way anchored fast. Liquid emulsion stencils are the most durable of all because they totally encapsulate the mesh. Therefore, it could be said that the durability of direct film stencils falls roughly midway between that of indirect stencils and liquid emulsion stencils.

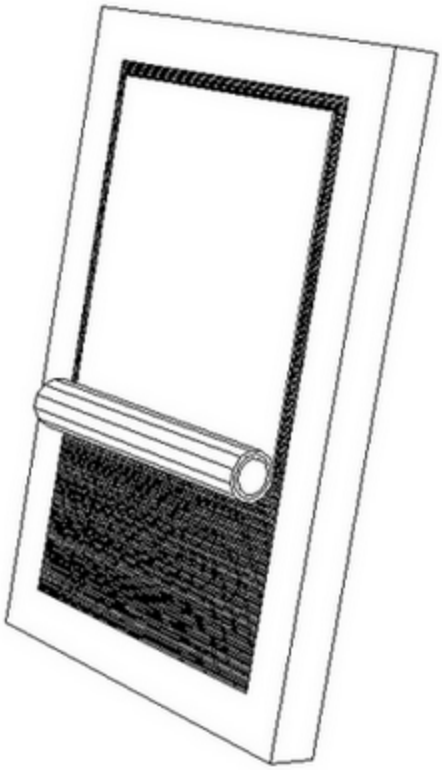

Fig. 16.1 The direct stencil film is unrolled with the emulsion side touching the wet surface of the screen.

Capillary films used to make direct stencils are available in regular diazo or SBQ sensitized photopolymer forms. They are available in a greater range of thicknesses than indirect films. The thickness of capillary film is always uniform so it can be counted on to provide an even deposit of ink. The perfectly flat and smooth surface finish ensures a tight seal against the substrate on the printing stroke resulting in very good edge definition. Much longer print runs are possible from capillary film-based stencils than indirect stencils. The fact that the former is embedded roughly two-thirds of the way into the mesh and the latter less than one-third of the way would account for the difference in durability, thus having a bearing on their respective service lives.

The methods used to expose screens mounted with direct capillary film are identical to the methods used to expose liquid emulsion coated screens. Since the carrier sheet is peeled off before exposure the inked or toner side of the positive is kept in direct contact with the capillary film. As always, using an exposure calculator and making a few test exposures can pay large dividends by preventing any waste of expensive materials and avoiding disruption caused by premature stencil breakdown later during production.

The procedure for washing out direct stencil films is the same as that for liquid emulsion stencils. A firm spray of water should be directed onto the exposed stencil over its full area. The washing out should be alternated from both sides until all of the unexposed material dissolves away. Even when the stencil receives optimum exposure there may be a few areas where the unexposed emulsion will not wash away cleanly. Rubbing gently with the fingertip should loosen this, leaving a well-defined stencil. Use absorbent tissue to mop up the moisture and dry it. Never direct a high-pressure jet of water for washing out freshly exposed screens.

Like indirect stencil films, capillary films too make possible rapid stencil production. A capillary film taken from its lightproof packaging could end up as a finished stencil on a ready to print screen within the space of one hour. The thickness of capillary films must be matched to the thickness of the mesh just as with indirect films. If a thin capillary film is mounted on a thick mesh, the entire film will be drawn up into the openings of the mesh!

The greatest advantage of direct capillary film is its versatility. It lends itself to all sorts of modifications to meet special demands. One of these is known as the 'direct/ indirect' stencil because originally the technique was based on indirect stencils. This method now employs capillary films instead, reinforced and strongly bonded to the mesh by the application of a compatible liquid emulsion coating on the squeegee side. There are two ways to do this. One approach is to apply two coats of a compatible emulsion using a scoop coater onto the squeegee side of the screen after mounting and drying the capillary film as usual but before removing the backing sheet. This is kept in place to prevent possible distortion and to preserve the dimensional stability of the stencil when the emulsion is drying. It is stripped off carefully after the emulsion has dried.

By performing the above operation in a slightly different manner, a thicker stencil may be produced using the same gauge of stencil film. In this method, capillary film cut to the required size is placed on a hard, smooth surface covered with newsprint. A degreased screen in a dry state is centered and placed on the film with the mesh contacting the emulsion. To carry out this operation efficiently and neatly a border of masking tape is laid out on the mesh around the stencil area but overlapping it slightly. Emulsion is dispensed from a squeeze bottle right across the masking tape at the top. A squeegee is drawn along the length of the screen, distributing the emulsion evenly over the capillary film and mesh. The liquid emulsion is given some time to soften the emulsion coating of the film and pull it upwards into the openings of the mesh. As the moisture content of the liquid emulsion is not sufficient to swell it fully, the capillary film penetrates the openings of the mesh only to a limited depth. After peeling off the masking tape, the screen is dried and the backing sheet stripped off carefully. The overall thickness of a stencil made this way would be slightly greater than that of a stencil made by adhering with water because more of the film would lie outside the mesh.

Whichever method is employed to prepare a stencil like this, after drying, exposing and washing out, the capillary film, mesh and emulsion coating become consolidated into a robust and inseparable mass. This assembly constitutes a stencil that combines many of the virtues of both liquid emulsion stencils and capillary film stencils. Because stencil material is deposited on both sides of the mesh, it is locked into position securely, thereby greatly increasing durability. This makes the emulsion coated capillary film stencil long lasting and ideal for extended print runs. If made with care, these stencils will provide reliable and excellent service, proving economical in the long run. Fig. 16.2 presents magnified cross-sectional views of the different types of mesh/emulsion systems.

Another valuable feature of this type of stencil is its ability to print images with sharp edge definition. This is possible because the lower surface is very flat and stands proud of the mesh. The only area in which it falls short of the indirect stencil is in printing very high-resolution matter. Here, it is thwarted by light scatter caused by the mesh and by its greater thickness. As you already know, thick stencils are not so good at reproducing fine details as thin stencils. The term 'direct-indirect' is not quite correct and it would be more appropriate to refer to this type as a 'combination stencil' as it is built up of two components, namely direct capillary film and liquid emulsion.

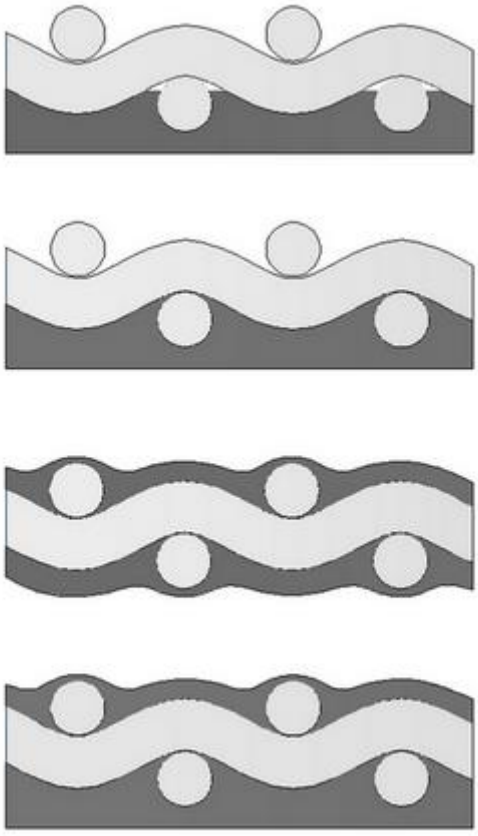

Fig. 16.2 Structural comparison of indirect stencil, direct stencil, liquid emulsion stencil and 'direct/indirect' stencil.

Direct films are also the ideal material for making very thick stencils for jobs requiring heavy deposits of ink. One example is high-density ink that is used to obtain raised printing effects with sharp edges. Very thick stencils for these applications may be formed by mounting heavy gauge direct films on the mesh and strengthening the assembly by coating with liquid emulsion on the squeegee side. Do not attempt to build up stencil thickness by coating on the upper surface as a thick emulsion layer will not be able to withstand the constant friction of the squeegee blade for long. Direct films are made in a wide range of thicknesses, ranging from 15 microns to 90 microns. For this work, the heavier films are chosen, and the thickness built up to the required limit by laminating them in some suitable combination. The first layer of direct film is attached to the mesh in the usual manner and dried. Additional layers are put on one after the other by drying and peeling off the carrier sheet each time. A compatible emulsion from the same supplier is diluted with water and applied liberally onto the surface of the outermost layer to create a bond. Then another sheet of film is placed on it, emulsion side down and smoothed down with a few strokes of the squeegee to eliminate any trapped air bubbles and surplus emulsion. Then the screen is placed horizontally, substrate side down in a dark cupboard, to dry.

Thick stencils can take a long time to dry, and the process cannot be hurried by setting a higher temperature in the drying cabinet. If this is done, the outside will appear perfectly dry while some moisture is still trapped in the middle. The correct way to dry would be to increase the circulation of air and the drying time instead of simply boosting the temperature. Thick stencils will also take longer to expose, therefore SBQ sensitized films that are from four to six times faster than diazo films are chosen for this work. Because a

lot of emulsion can go waste if the exposure is misjudged, it would be prudent to do some testing during the first few attempts at exposing thick, built-up stencils. As always, it is better to take a chance on the side of overexposure than underexposure.

Washing out is performed by using a cold-water spray on both sides. An adjustable nozzle is useful as the washing can commence with a low-pressure spray. If necessary, the water pressure may be increased for the final rinse off, but the use of excessive pressure must be avoided. After drying fully, both sides should be subjected to post exposure in turn to further toughen the stencil.

Direct stencil films are primarily intended for use with solvent-based inks, UV curable inks and plastisol inks. New film types have been introduced recently for use with water-based inks. It is very important to match the stencil type to the variety of ink to be used for printing.

There will always be differences between the stencil films marketed by various suppliers. Sometimes a supplier may offer what is essentially the same product in many guises with some variations in properties that may call for different processing methods. Information regarding the product will be found in the package or available with the retailer. This information must be referred to because many screen-printing products intended for similar end uses possess quite dissimilar properties so that a generic approach cannot be adopted when handling and processing them.

It is a good idea to wear lint free fabric gloves when handling stencil films. After mounting the film and drying, the screens may be put in black plastic bags and stored in a lightproof enclosure for a period of up to one week before exposure.

Nearly all photo stencil films produced today are marketed in a pre-sensitized state. A type of film that was very popular some time ago was distributed in an unsensitized state. The medium that was used to bond this film to the screen also served to sensitize it at the same time so that it could be exposed later, after drying. The chief advantage of this material was that it possessed a very long shelf life which could extend to three years or more if stored with care. The stability may be attributed to the fact that no reaction can take place in the absence of a sensitizer. Thus, it proves ideal for the hot and humid conditions that prevail in tropical countries.

Chapter 17 – Reclaiming Screens

Sometimes serious flaws may occur on newly made stencils. If it is not possible to correct them, the stencil can be removed from the mesh and a new one put on by re-coating the screen and exposing it again. At the end of a long production run when a stencil would be of no further use, it may be stripped off with the aid of chemicals that leave the mesh intact and used again to carry a fresh stencil. Screens carrying worn out or damaged stencils may also be salvaged by getting rid of the unwanted stencil using certain chemicals known as mesh strippers. By reclaiming the screens thus, they can be used repeatedly, reducing the inventory, which helps to conserve resources by saving much time, materials and storage space.

The early screen printers resorted to rather crude methods to get rid of the unwanted stencils. They rubbed and scrubbed the screens with scouring powders and bleaching powder. These harsh materials tended to weaken and even damage the mesh and so they are no longer in vogue. Specially formulated mesh strippers are now used exclusively for this purpose as these products perform the job very effectively and efficiently with the minimum of fuss. Mesh stripper is marketed as a crystalline white powder, in the form of a gel or as a concentrated solution that must be diluted before use. The active ingredient in standard strippers is sodium metaperiodate (meta-per-iodate), an oxidizing agent. It is the oxidizing action that causes the stencil to disintegrate. The liquid formulations may contain additives such as surfactants to improve the wetting action that helps to speed up the process. Mesh strippers may be based on other chemicals sometimes and it is best to select the product recommended by the stencil material supplier.

It is necessary to get rid of all traces of printing ink and oils from the old stencil before attempting to break it down with the stripping solution. This is because their presence will tend to inhibit the chemical reaction between the stencil and stripping agent making it far more difficult to dissolve and remove the old stencil. Water resistant stencils are washed in water containing detergent and rinsed thoroughly. Solvent resistant stencils are first cleaned using the appropriate screen wash, after which they are washed using a detergent and water. Some authorities recommend an additional washing stage using a mesh degreaser as this removes every vestige of oil and grease from the stencil enabling the mesh stripper to work fast. This degreaser is the same as the one used earlier to clean up the mesh prior to application of the stencil.

The stripping solution is prepared by dissolving the crystals in water in the ratio of 10 grammes per liter. A stronger solution may be prepared by using a smaller quantity of water, say 500 milliliters of water per 10 grammes of stripper. It will be seen that even a strong solution is of low concentration and therefore very economical. The mesh stripper works best when it is well diluted. Material purchased in the form of a concentrated solution must be diluted with water as per the directions on the bottle as products from different suppliers may not be of identical strength. If mesh stripper is purchased in pre-diluted, ready to use condition, it must be used as it is, but it is not economical to use this type of product.

Before the stencil can be removed, all frame tape applied to the surrounding areas must be removed to expose the stencil fully. A clean rag dipped in the prepared solution is applied liberally and worked all over its surface on either side. The stencil will soon begin to dissolve and gradually break down. As more mesh stripper is applied, the liquefied stencil will run off. Indirect stencil films are the easiest to strip off as they are stuck to the mesh on only one side. In this case, it is sufficient to apply the stripper to the squeegee side to dissolve away the bond between the stencil and the mesh. When this happens,

the stencil breaks down and drops off in large pieces. Direct stencil films require a little more effort to strip off as they are bonded more intimately to the mesh. Liquid emulsion stencils penetrate the entire thickness and cover the stencil on both sides. The mesh stripper should therefore be applied to both sides and rubbed all over until the stencil disappears. For very thick stencils, apply only on the squeegee side repeatedly and try to break it down into pieces without attempting to dissolve the entire bulk of it. The screen is washed out thoroughly with a powerful jet of water, starting from the lower end of the screen and working upwards. The other side is also washed the same way to remove all traces of the stencil. The gentle spray of water customarily employed for washing out exposed screens will not get the job done.

Mesh stripper in gel form is sometimes more convenient to use. It sticks to the spot where it is applied without running off or spreading all over the screen.

Mesh stripping solutions possess a curious property that can take novice screen printers by surprise. While they are efficient at getting rid of stencils, they will also render them permanent and irremovable if allowed to dry up in the middle of the operation! Therefore, any stencil removing activity must never be interrupted part way through as the stencil will dry up and harden permanently and thereafter it will not be possible to reclaim the mesh at all. If this happens, the only way to give a new lease of life to the screen frame will be to rip off the old mesh and install a new one instead. This role reversal exhibited by mesh stripper is just one of the many odd phenomena that screen printers constantly encounter when working in the print shop.

A reclaimed screen will often carry a ghost image of the previous stencil. The ghost image may be seen more clearly under certain lighting conditions and when viewed from certain angles. These images are caused by the presence of stencil residues trapped between the intersecting yarns of the mesh. Ghost images can and do compromise the quality of any stencil that may be put on the mesh subsequently. Therefore, it is necessary to perform an additional operation to get rid of the vexatious ghost image. Treatment with a special preparation formulated to deal with ghost images on screens eliminates them by destroying the residues chemically.

A preparation known as Haze Remover is dabbed onto a wet screen and scrubbed with a screen cleaning brush only on those areas where the ghost image appears. Both sides must be scrubbed, and the screen kept aside for about 6 to 8 minutes for the chemical to soak in and do its work. Prolonged treatment will weaken the mesh and so the haze remover is washed off at the end of this period making sure that no trace of it is left behind. Haze remover contains a highly caustic ingredient, specifically sodium hydroxide and so caution must be exercised when working with it. Eye protection and gloves must be worn when using the same as the strong alkali can cause serious eye injury and convert skin to soap. Even if the mesh has been treated with haze remover, it would still be necessary to follow up with a degreasing operation just before applying the next stencil. Dry the screen and store it carefully until it is needed again.

It may prove difficult or impossible to reclaim screens that have been treated with water resistant hardener. Anyway, you can try your luck. If the stencil proves recalcitrant and refuses to budge, then the only alternative is to remove the mesh by cutting it off and trimming neatly all loose yarns. Frame adhesive thinner cannot be used to soften the hardened joint. Another product known as frame adhesive stripper intended for this purpose may not be freely available. In any case, it is effective for removing certain types of adhesives only and requires the joint area to be immersed in the stripper overnight, followed by scraping off the remnants of the old mesh with a sharp instrument and cleaning up. As this could prove to be a messy operation, the best solution would be to smooth down the old mesh with emery paper, put on the new mesh on top of it and

adhere with frame adhesive as before. Repeated stacking of the mesh on the joint face of the frame will not usually cause any problems. To prevent the occurrence of another odd phenomenon, remember to use the same type of adhesive always!

In general, solvent resistant stencils are easier to reclaim than water resistant stencils. Sometimes you may find that despite prolonged application of mesh stripper, it proves impossible to remove the stencil from the mesh. Usually, the cause of this problem could be traced to the faulty execution of certain procedures at the pre-production stage. One reason could be that the exposure was carried out before the emulsion was completely dry. Therefore, always pay attention to this point. Another reason could be that the stencil was underexposed. In fact, correctly exposed or even overexposed stencils are much easier to reclaim than underexposed ones. This is one more reason why post exposure of all screens is strongly advised.

Some indirect stencil films are based on a gelatin formulation. This type of stencil is best removed with a stencil stripper made especially for use on gelatin-based films. It is a yellow liquid that works more effectively on this type of stencil than the regular stripper.

All stencils tend to become harder and tougher naturally with the passage of time. A screen that has been kept in storage for several months after fulfilling its production role may prove difficult to reclaim later. It is always better to reclaim screens within about a month after they have served their purpose without keeping them lying around for long periods. This way, a ready supply of blank screens would be available for use at all times.

The reclaiming operation is similar in many ways to the mesh preparation procedure discussed in Chapter 10 except that a different set of chemicals are used. Refer also to Fig. 10.1.

Chapter 18 – Printing on Paper

Printing on paper, paper stickers and paperboard may be carried out using the simplest of equipment. What is required is a smooth, hard and flat baseboard, a pair of hinge-clamps, the stenciled screen, squeegee and of course, the consumables. The screen is firmly clamped to the hinges by one of its shorter sides. Both clamps must be aligned carefully to ensure their hinge pins lie on the same axis. The ‘snap’ or ‘off contact’ must be set carefully by keeping spacers under the clamps or by making use of any built-in provision for adjustment. At the front end, cardboard or rubber spacers may be pasted under the corners of the screen to set the gap correctly. Compact tabletop units comprising a baseboard with an integral hinge arrangement and removable screen are available commercially for those who wish to get off to a quick start in screen printing. The hinge is spring loaded so that the screen can remain in the open position without having to be propped up. Ideally, a printing table intended for printing paper should have a surface drilled with small holes for holding the paper securely in position by means of suction. A sealed chamber attached to the lower surface of the table, right under the holes, connects to a small vacuum pump through a foot pedal actuated valve controlled by the operator, who will use it for applying and releasing the suction. In mechanized screen-printing devices, the vacuum is applied as the screen is lowered and released as it is raised. Suction holes lying outside the area of the paper being printed must be temporarily sealed off with adhesive tape to prevent loss of vacuum.

When printing onto any surface, including paper, it is important to locate the image in the correct position and orientation on it. If only one color of ink is to be printed, then it is not difficult to arrange this because the paper needs to be aligned only once. To accomplish this, take a sheet of paper from the stack you are going to print and stick a long narrow strip of paper right across the middle of its shorter side. Keep the paper on the printing table with the long strip underneath and lower the screen onto it. The ends of the long strip of paper would now project beyond the left and right sides of the screen. The outline

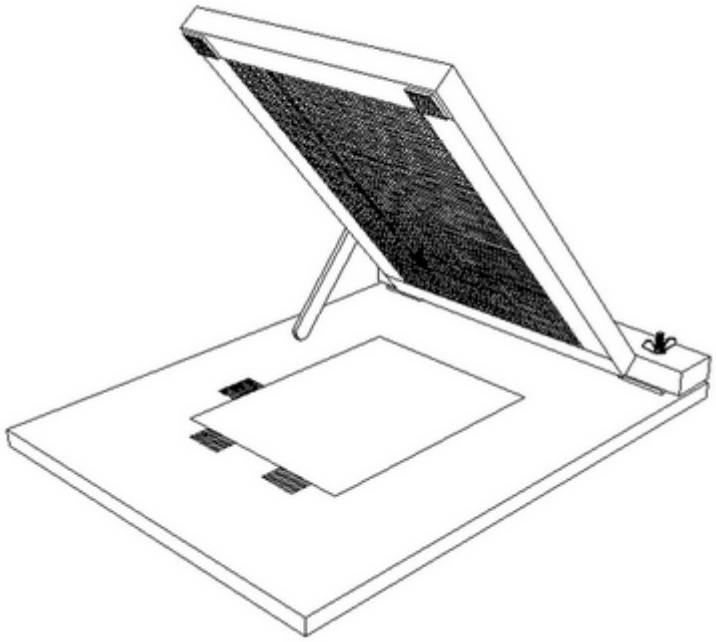

Fig. 18.1 The registration guides are taped to the printing table as shown to locate the paper in the correct position.

of the sheet of paper would be visible through the translucent stencil. Holding the ends of the strip with both hands adjust the position of the paper until its outline frames the subject matter on the stencil in a centered position. The clearance provided by the 'off contact' feature will allow the paper to be moved around freely under the screen. Switch on the vacuum now to hold the paper in this position or tape both ends of the long strip of paper to the printing table. Now raise the screen up.

Registration stops are used on printing tables to ensure that the print falls on the identical location on every sheet of paper in the stack. Tape three of these registration stops along the sides of the paper onto the table, two lined up by the bottom edge and one against its left edge as shown in the illustration. It is not a good idea to use more than three stops as it can lead to inconsistent lining up of the paper. Once this is done, you can be sure that every print made during the production run will fall in the same position on the paper when it is located by the registration stops. Remove the aligning sheet with the attached strip of paper from the table but do not discard it until the work is over.

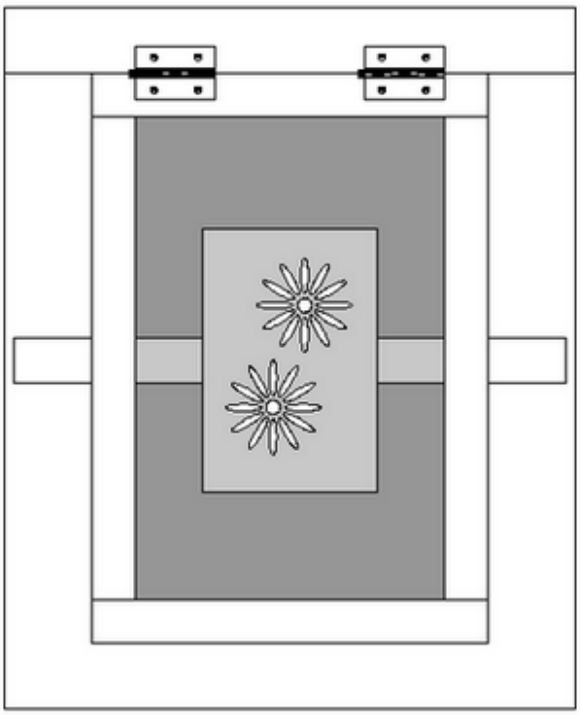

Fig. 18.2 A long strip of paper pasted to the alignment sheet is used to center it correctly with respect to the image.

Sometimes it may be difficult to see the outline of the paper against the printing table if they are both the same color or when the stencil is dark. You will then be unable to position the paper on the printing table correctly due to the fuzzy view obtained. In these instances, you can adopt an alternative approach to align the paper. You simply need to tape the left edge of a sheet of translucent paper such as vellum, thick tissue paper or oil paper onto the middle of the printing table. This sheet should be somewhat larger than the paper that will be used for the print job. Now lower the screen, put some ink and print on the translucent paper. Then take a sheet of paper from the stack kept for your print job and position it carefully underneath the transparency so that it is centered and aligned perfectly with the imprint appearing above it. Flip the transparency out of the way without shifting the paper underneath. All that remains is to affix the registration stops against the bottom and left side of this paper as described above. Now you can be sure that every sheet will receive the impression at the identical spot ensuring consistent alignment.

You can make the registration stops yourself out of thin but stiff plastic sheet. Suitable materials are polyester and cellulose triacetate. Old photographic negatives or even X-ray films may serve the purpose. The thickness of the sheet should be slightly greater than the thickness of the paper. Make about a dozen at a time, so that you always have a supply handy. Each registration stop is made up of two thin sheets of plastic stuck together with rubber cement or any suitable adhesive. Both pieces are the same width, but one piece is longer than the other by about 3/16^{ths} of an inch or 5 mm. So, to make three stops, cut out three pieces measuring 1½" x 1" and three pieces measuring 1½" x 1 3/16". Paste a smaller piece and a larger piece together to make each stop and you will find that on one side the larger piece will project beyond the smaller one by 3/16" as shown in the illustration. Clean off all traces of adhesive below the overhanging portion, as the edge of the paper will rest under it when it is stopped by the edge of the plastic piece underneath.

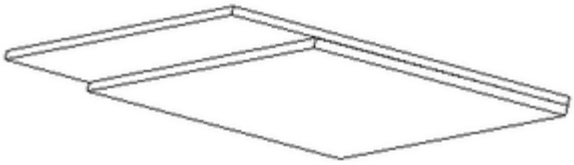

Fig. 18.3 Positive registration stop for thin stock.

When the registration stops are fixed in position, the sheet of paper that is brought to rest against them for printing should slide in neatly under the overhanging portions. If necessary, they may be bent up just a trifle to facilitate this. Colored plastic sheets are better than clear sheets as the registration stops should be plainly visible on the printing table. If you can find only clear material, color it with a permanent marker so that the stops can be seen easily. The edge of the squeegee blade as it passes over the registration stops under the stencil reacts to them as if they were bumps, which indeed they are. A squeegee of medium hardness would be able to accommodate this irregularity by flexing slightly every time it passes over a stop, but a hard squeegee may keep scuffing the stencil and eventually damage it. Therefore, do not use a hard squeegee with this type of registration stop, which is used only when printing on thin material like paper. Its great advantage is that it will locate the paper positively without allowing it to slide over and above it.

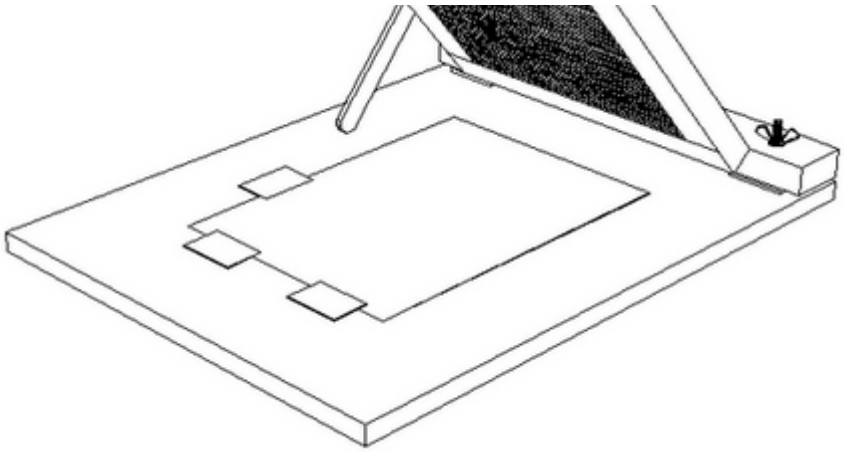

Fig. 18.4 The overhang feature of the guides provides a positive stop by preventing the paper from sliding over them.

Probably the trickiest operation that screen printers must perform is setting the registration accurately whenever they must print more than one color of ink on the same work piece. Since this is a routine they must perform all the time, it is important to know how to set about it correctly. In fact, the issues relating to registration need to receive attention as early on as the time at which the photopositives are made. Graphics programs have provision for adding registration marks at the four corners to facilitate precise alignment of separations and this feature proves invaluable when they must be printed in sequence later on to form the complete image. Therefore, when making color-separated photopositives, remember to add registration marks at the corners by clicking the appropriate checkbox in the print dialog box. These marks are essential for both flat color and halftone color separations.

When printing multicolor subjects, a separate screen is required for each color. Registration marks are burnt into all the screens so that when a print is made, these marks would also appear on the work piece. But the marks are put there only to help align the screens to ensure perfect registration. Once this is accomplished the registration marks are suppressed. Proceed by positioning a sheet of paper on the baseboard under the first screen at the correct position as described earlier for single color printing. Tape three registration stops in place. Make a print with this first screen and ink color so that the registration marks appear along with the main subject on it. This will be the alignment print so keep it safe somewhere. Now seal off the registration marks by sticking adhesive tape on the lower surface of the screen right under them so that they do not show up on the production prints. Print the entire lot of paper with this screen using the matching ink.

Next, remove the screen and the registration stops on the baseboard. Clamp the second screen in position. Align the registration marks on the alignment print with the registration marks on this screen by viewing through same. Apply the vacuum or tape this print to the table to keep it in position. The purpose of the alignment print is to help redefine the position of the registration stops because they must be shifted every time the screen is changed. Raise the screen and tape the three stops along two of its adjacent sides so that they will define the position of the paper with respect to the second screen. Remove the alignment print. Seal off the registration marks on the screen by applying adhesive tape under them and print the second color ink on the entire lot. Repeat the whole procedure with the remaining screens until all the colors are printed. The result should be a stack of paper printed with multicolor matter, displaying perfect registration.

There is another way to position work pieces with consistent accuracy and obtain perfect registration when printing several color inks sequentially using multiple screens. This method also makes use of a transparent material to establish the position of the imprints accurately. In this case, the left edge of a large sheet of clear, flexible plastic film is attached to one side of the printing table with some thick, strong adhesive tape so that it can be opened and closed like a book cover. When opened fully, the plastic sheet hangs down off the edge of the printing table. Clear cellulose film is a good material for this purpose, but other clear types of plastic sheet may also prove suitable. If the clear sheet shows a wavy surface without lying flat, place a smooth flat plywood board weighted with objects on top of it overnight. The first screen is fitted on the hinge clamps and the matter is printed onto the surface of the plastic sheet after it is spread out flat on the baseboard. This will give you a clear indication of the exact location where the print will fall. Slide a piece of paper from the stack you will be printing on underneath the plastic sheet and maneuver it into the correct position with respect to the printed image. Gently flip over the clear sheet off the table without disturbing the position of the paper underneath. Attach three registration stops in the usual manner along the sides of the paper. Prepare an alignment print first with this screen including the registration marks to use as a reference. Then seal off the registration marks with adhesive tape applied on the lower surface of

the screen, as you do not want them on the production prints. Now print the entire stack of paper with the first ink and then remove the screen and registration stops.

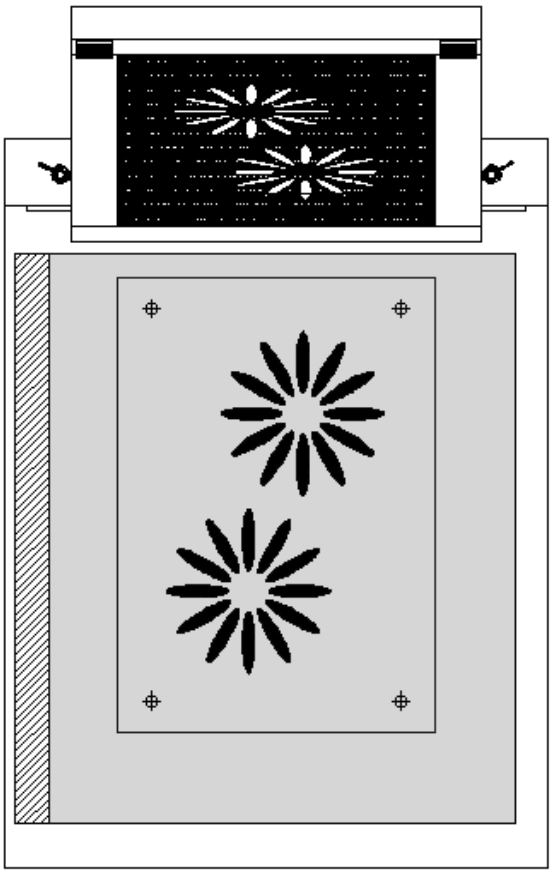

Fig. 18.5 A clear plastic sheet is used as a temporary substrate to indicate the exact position where the image will be imprinted.

Now fix the second screen onto the clamps. Cover the printing table with the clear sheet once again and wipe off the earlier print. Put the second ink on the screen and print on the clear sheet. Slide the alignment paper printed with the first ink under the clear sheet and align the registration marks on the former with the registration marks on the latter until the two sets of marks are perfectly superimposed. Flip the plastic sheet over without disturbing the alignment paper. The registration guides must be set once again for the second screen and fixed in the usual manner to the printing table. Proceed by blocking the registration marks on the screen and printing the second color ink onto the entire lot of paper in the production run. Continue to print the remaining colors by repeating the procedure. The screen and registration stops, once they are aligned properly with respect to each other, must remain in place until the entire print run has been completed. For very large orders, a separate printing table and screen may be set up for each color to permit fast throughput after allowing sufficient time for the ink to dry between screens. Naturally, you will have to engage more operators to do the printing simultaneously.

There is a way to print multicolor images using a single screen in the case of blocky subjects consisting of color areas that are comfortably separated from each other. Fig. 18.6 shows such a screen that is to be printed in three colors as indicated. Make a photopositive that includes all the color areas and expose a screen coated with solvent resistant emulsion through it. Wash out the screen and dry it well. Use screen filler to seal

all the open areas of the stencil except those that are to be printed with the first color. Use a stiff cardboard or plastic piece with a neat edge to level the coating. The screen filler dries fast, and the first color can be printed on all the work pieces after setting up the screen and registration stops. Remove the screen and after cleaning off the ink on it wash it in water to get rid of the filler. Use filler again to seal off all open areas other than those corresponding to the second ink color. Fit the screen in position and shift the registration stops to the new position. The areas printed with the first color may be used to align the paper without bothering with registration marks. It helps to print the most widely distributed color first to enable easier registration. Print the second color onto the work pieces. Repeat the procedure to print the third color. This way, even six colors may be laid down using a single screen that has been exposed just once and without registration marks. Screen filler works the same way as block out but can be easily removed as it is soluble in water and is therefore commonly used for the temporary blocking out of stencils. It can be used with oil and solvent base inks only.

Fig. 18.6 The same stencil can be used with blocky images to print several colors by the selective application of temporary filler to different image areas.

Single color halftone printing may be performed by laying down the ink through a halftone screen. The mesh count of the polyester fabric used for the screen must be related to the resolution of the halftone image on the photopositive. The general rule is that the mesh count of the screen should be about three times the line count of the halftone image to be able to reproduce accurately the dots, which vary widely in shape and size. This is important because the quality of the printed image is very much dependent on how closely the dots on it match those on the photopositive. Therefore, a screen with a mesh count of about 180 openings per inch should be used to print a 60-lpi halftone image. The multiplier of 3 may be increased or decreased a little to improve or diminish the quality of the translation to suit the requirements.

Another property of the halftone stencil is that it cannot reproduce a dot that is smaller in diameter than its thickness. This point has been touched upon earlier, but it must be stressed that it is difficult for a stencil to print lines or dots that measure less than its thickness. It follows that the finer the detail it is desired to print, the thinner must be the stencil. Very fine mesh should be picked for this purpose and paired with a thin stencil film or a thin coating of liquid emulsion.

Full color halftone printing may be accomplished by preparing four screens to print the process colors cyan, magenta, yellow and black. Special CMYK ink sets are made for this purpose. Matching screens exposed through color separated halftone photopositives are used to print the colors in sequence, after allowing each ink to dry. The screen angles must be set correctly when printing the photopositives as explained in Chapter 14. Registration marks must be put on the screens and the placement of the registration guides will have to be adjusted for each screen.

The maximum resolution that can be achieved by screen-printing on paper is governed by several factors such as the quality of the paper, the quality of the ink, the accuracy of the screen and the press setup. For process color work, precise paper handling and spot-on registration are essential for producing high quality output. Such things as mesh tension and 'off contact' can play a big part in achieving good results as well. A resolution of 110 lpi on coated paper may be regarded as excellent.

Let us now take a brief look at the inks. A wide variety of inks can be used to print on paper, plain paper stickers and paperboard because their surfaces are receptive to just about any formulation. It makes sense however to choose inks that are specially designed to match the end use as it is more efficient, economical and safer to do so. There are inks for use on rough and uncoated paper and inks for use on coated and premium grade paper. Uncoated paper is more receptive to ink than coated paper but is only suitable for low resolution work. Most inks for paper are oil or solvent based but water based inks are also now available. They are known as poster ink, lacquer ink, S/S ink and all-purpose ink. The stencil material must be picked to match the type of ink. When printing on paper use a squeegee of medium hardness, i.e., 70 durometer. Have all materials handy to avoid interruptions to the smooth flow of work. Prepare the ink to the correct consistency because it may be too thick as it comes from the container. Use a suitable thinner to adjust the flow properties of the ink. The drying time of the ink will not only depend on its formulation and the absorptive properties of the substrate but will also be influenced by the temperature, humidity and circulation in the press room.

The "snap" or "off contact" must be set to about $1/8^{th}$ of an inch when printing on say, A4 size paper. Printing ink must be distributed liberally over the entire active area of the stencil before the print is pulled to ensure proper ink coverage throughout. The thin layer of ink left on the mesh after each printing stroke can dry very fast and will eventually block the openings of the mesh. Therefore, the stencil area should always remain covered by a thick layer of ink, as it will then be less prone to drying up. To ensure this the puddle of ink should be pushed back lightly with the squeegee without pressing down on the mesh immediately after every printing stroke, before raising the screen to remove the printed sheet. However, despite all efforts the screen will be blocked by dried ink now and then while printing is in progress. When this happens, the blockage can be cleared up by wiping both sides of the screen carefully with a soft rag dipped in a suitable thinner or solvent. Dry the bottom of the screen with another absorbent cloth before resuming printing. There is also an aerosol product known as 'screen opener' that may be sprayed on the dried ink layer to clear the blockage. The printed work pieces should be transferred to a drying rack straightaway.

Dusting flock powder onto the wet ink immediately after printing and shaking off the excess covers the printed area with a velvety finish that has an attractive look. Original flock material is made by cutting fine textile fibers to very short lengths. Surfaces coated with flock material have a soft, plush feel. They are used as a finish on invitation cards and similar items. Flock powder is available in many colors. The design is printed with a thick coat of slow drying ink roughly the same color as flock powder. As soon as the card is removed from the printing table, the powder is sprinkled onto the image area liberally. The card is shaken a little to distribute the material all over the image area and work it into the wet ink. It is then held vertically and in a curved shape to make it rigid and the lower edge tapped on a level surface to shake off the surplus powder. The card is then put aside to dry. The surplus powder is returned to the container for reuse. Flock powder sticks better to some types of inks than others. Gloss ink for example works better than matt ink. Mixing in a little adhesive of the right type will enable the use of flock powder with a wider range of inks.

Another material that is often employed to enhance the look of printed matter is embossing powder. This product is available in a wide range of colors, textures and in a transparent form. Embossing powder is used to obtain a striking raised effect that can dramatically transform the appearance of printed output and add value to the product. The method of application is the same as that for flock powder, but an additional step is required. After the ink has dried, a special device known as a heat gun is used to melt the powder, which rises up to form a shiny, firm coating with a relief effect. Heat guns are specially made for embossing work but any industrial heat gun, such as that employed to apply shrink-wrapping may be used if kept at a lower heat setting. Heat guns work like hair dryers but are designed to provide a gentler and narrower stream of air at a higher temperature. If you are planning to engage in embossing work, get a heat gun because a hair dryer will simply blow off the embossing powder without melting it. Concentrated heat and less blowing is the key to successful embossing.

Best results are obtained by using ink the same color as the powder but some interesting though unpredictable effects may be obtained by applying lighter colored powders on dark inks. Clear embossing powder allows the underlying ink color to show through with a relief effect. The powders are supplied in regular, metallic, pearlescent and glitter forms with various textures. Some of these powders tend to cling to the surface of the paper on the un-inked areas too due to static charge and may be troublesome to remove. Wiping the surface of the paper with anti-static cloth just before printing will help eliminate this problem. The heat gun must be kept moving all the time as the paper will start burning if the very hot stream of air is directed at the same spot for long.

Whatever the type and class of screen-printing work carried out, material compatibility should be observed with care. The first thing to consider is the ink receptivity characteristics of the substrate. The ink should be chosen to suit the substrate and the stencil material should be chosen to match the type of ink. The thinner and screen wash should be compatible with each other and the materials with which they will come into contact during use. For instance, the stencil material may become badly eroded and break down prematurely if used with the wrong type of ink or cleaned using an incompatible thinner, screen wash or detergent. When the work is finished, all leftover ink should be scraped gently off the screen and squeegee and transferred to a separate jar. It should not be returned to the original container to avoid contamination because additives may have been mixed in along with some extraneous matter.

The printing screen, squeegee, spatulas etc. may be cleaned by wiping thoroughly with a rag dipped in a suitable thinner. Several types of thinner are available but you must pick one recommended for use with the chosen ink. PVC thinner is generally safe to use with most stencil materials, but nitrocellulose (NC) thinner intended for use with automotive spray paint is too strong for cleaning up printing screens. Special screen washes are also available for this purpose, and these should be employed as directed. Tap water will serve to clean up screens and implements in the case of water-based inks, with the addition of a little mild detergent if necessary. The screens must be dried and stored neatly in a rack where they will remain safe when not in use.

Chapter 19 – Printing on Textiles

Printing on textiles is a specialized activity that is pursued by a large proportion of screen printers. Fabric is not as smooth, hard or impermeable as other materials like wood, metal, plastic or board that also receive this finishing treatment. Even tissue paper is able to muster a degree of stiffness and dimensional stability that surpasses that of most fabrics. When placed on a hard, smooth printing table, fabric tends to shift easily from its position, and it may have wrinkles on it too. This can prove especially troublesome when printing multiple colors that call for perfect registration. It is not possible to solve the problem by applying a vacuum as in the case of paper because cloth is a porous material. Even if printing is carried out somehow, the wet ink will cause the material to stick to the bottom of the screen and come up with it as it is raised.

Therefore, these problems must be addressed before attempting to print on textiles. Screen printers, being a rather ingenious lot by nature, long ago devised a neat way to overcome such impediments. They simply stick the fabric to the printing table with a temporary adhesive. This adhesive is specially formulated to possess great tackiness by resisting complete drying. It is called by different names in different countries as platen adhesive, pallet adhesive, table glue and sticker gum. It is a thick white paste, which when applied onto a smooth, hard surface dries partially and turns into a colorless and tacky coating that will grip instantly and firmly any porous and pliable material such as cloth that is pressed into contact with it. The cloth may at any time be peeled off cleanly without getting any adhesive residue transferred onto it. This can be done repeatedly because the substance is able to act as a reusable adhesive that provides temporary adhesion. The adhesive paste is spread on the printing table with a piece of stiff cardboard or plastic and allowed to dry for about 15~20 minutes until it turns from white to clear. It is not easy to apply the glue uniformly as it resists any attempt to achieve an even coating. Fortunately, the glue is also available in aerosol form that makes smooth application quick and easy, and this type maintains the tackiness for a longer period too. The aerosol adhesive is rather more expensive but very convenient to use. Just avoid breathing in the fumes. Use thicker coats for thicker materials.

Printing table adhesive becomes loaded with loose lint from the workpieces and eventually loses its tackiness. It is possible to prolong its efficacy to some extent by wiping with a damp sponge at intervals, but additional coats will be needed as work progresses, to maintain the tackiness. Soon, repeated application of the adhesive, layer by layer, will cause the printing surface to become increasingly uneven, as the thickness tends to build up non-uniformly. Therefore, the printing table must be cleaned up fully and started off with a fresh coat of adhesive periodically. Cleaning is accomplished by wiping the surface with a rag dipped in kerosene or turpentine and in the case of certain aerosol adhesives, with the specified solvent.

For fabric printed with a single-color ink, the procedure is quite straightforward. A single panel of the garment or whatever item is placed lightly on the glue covered printing table, positioned correctly, and spread out neatly to eliminate all wrinkles, taking care not to distort the material. It is then pressed down firmly all over to fix it immovably. When the screen is lowered into position, the spacers glued under its outer corners come to rest on the fabric and maintain a gap between it and the bottom of the screen. At the other end, the gap is set by adjusting the seating of the hinge clamps that hold the screen by one of its shorter sides. That of course is the ‘off contact’ so essential to prevent ink from spreading out under the screen. The operator should stand in front facing the free end of the screen.

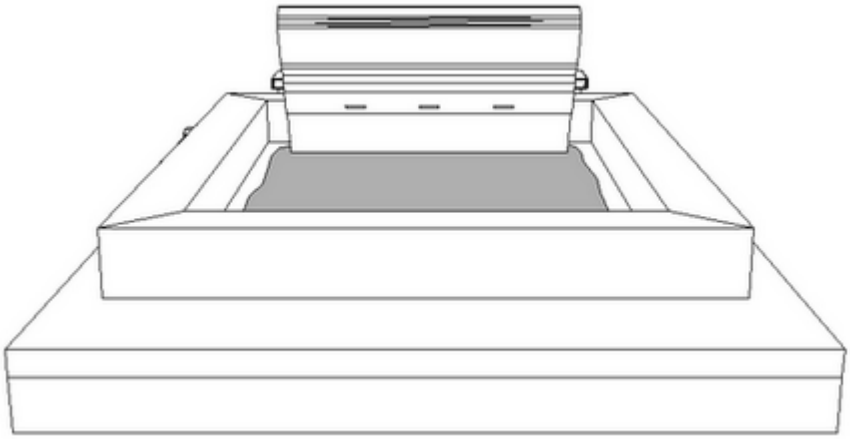

Fig. 19.1 The entire image area needs to be flooded by a layer of ink to ensure full coverage and lay down an even deposit of ink on the substrate.

To commence printing, place a dollop of ink on the screen at the end nearer to you with a spatula and spread it across the width of the screen. Use the squeegee to distribute the ink all over the printable area by pushing it forward lightly without pressing down on the mesh. The ‘flood stroke’ is necessary to ensure that the entire image area on the stencil is covered by a layer of ink to obtain a good deposit on the substrate during the print stroke. On automatic machines, there is a separate flood bar to perform this action prior to every printing stroke. Following this step the actual printing may be performed.

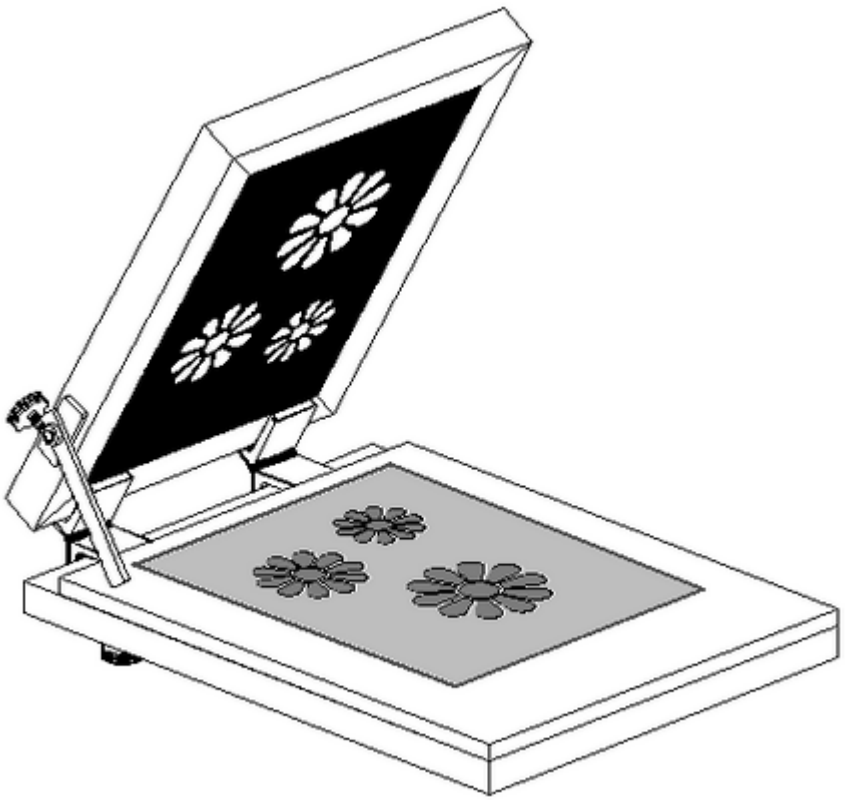

Fig. 19.2 After printing, the fabric can be peeled off the platen.

Grasp the squeegee firmly with both hands and place it at the further end of the screen at an angle between 45 and 60° with the handle inclined towards you. Now press down on it to bring the mesh under its edge firmly into contact with the substrate and pull steadily at a constant speed. The passage of the edge of the squeegee over the stencil will push most of the ink ahead of the blade but some ink will be forced through its open areas onto the surface being printed. Follow with a flood stroke immediately after the printing stroke to cover the mesh with a layer of ink. The purpose of this action is to keep the mesh moist so that the residual ink on it will not dry quickly and clog the openings. When printing on textiles, it may be necessary to perform the printing stroke more than once to obtain satisfactory ink coverage, but it should always be in the same direction, i.e., towards you. Now raise the screen up and examine the print. If everything has worked out well, you will be rewarded with a good print; if not, try flooding the screen and pulling the squeegee again.

When you get a good print, peel off the fabric carefully and put it on a rack or drying line. Center another piece of fabric, adhere it to the table and continue printing. Heavily sized cotton fabric should be washed well to remove the sizing to ensure good ink adhesion. If more than one color is to be printed then it will be necessary to install a more elaborate arrangement of printing screens, in which each screen will lay down a different color. We shall see later how this can be accomplished without slowing down production to a crawl.

Notwithstanding what was stated earlier, it is possible to print on fabric without using table adhesive. A padded, canvas covered table must be used as the printing surface. Two layers of ¼" thick felt covered by a taut canvas would possess just the right properties for this application. The fabric to be printed, which must be ironed first to free it of wrinkles, is spread out evenly on this surface, pressed down firmly and smoothed onto it. The nap on the fabric and on the canvas cause both to cling together and so prevent the material from shifting. If the material proves slippery, it can be secured positively by pinning it to the padded table along its borders. When printing is carried out on a compliant surface like this, no provision is made for 'off contact' and the screen is placed directly on top of the textile material. Hinge clamps are generally not used either and an assistant holds the screen in position while the printer works the squeegee. Yardage material is kept on a long table and printed in this manner, with the screen moving down the table by being shifted sideways after every print stroke. This approach works only for simple and bold designs using a limited number of colors.

We may now look at the inks. Compared to paper printing inks, textile inks must be able to meet conditions of service that are far more rigorous. In the case of an outdoor banner, this will be exposed to the harshness of the elements in which UV light also plays a part due to its powerful bleaching action on all organic coloring matter. Garments go through repeated laundering cycles, which can cause the inks to wash out because detergents are hard on them. Regular ironing will further contribute to the dulling of colors. The constant stretching of garments is another factor to be considered because the substrate keeps changing its dimensions along with the print, causing mechanical stresses in some types of ink.

Solvent base inks, pigment inks and plastisol inks are the three types used to print on textiles. Solvent base inks are used to print banners, outdoor advertisement and display material but not garments, as they cannot be laundered without becoming sticky. Many of these inks are also used for printing on other surfaces. Solvent resistant emulsions or films are used to make screens for use with solvent inks. Special thinners and screen wash liquids are employed to clean up the screens after use as these stencils have poor water resistance. Solvent inks are discussed in detail in the section dealing with printing on plastics.

Pigment inks are commonly used for the screen printing of garments. The pigments in these inks are stable, brightly colored compounds in the form of very fine, insoluble particles. Unlike most dyestuffs, the pigments have no natural affinity for textile fibers because they are chemically unreactive and insoluble as well. For printing on textiles, the pigment is always mixed with a medium known as a textile binder. Binders are long chain organic molecules based on various acrylate, butadiene and styrene monomers. Binders work by attaching themselves tenaciously to the fibers of the fabric and to the pigment particles, trapping them securely within their structure when they undergo a polymerization reaction promoted by the action of heat in the presence of a suitable catalyst, usually referred to as the 'fixer'.

Binders are usually in the form of viscous, white colored pastes. They are blended into copolymers to impart the right combination of properties. Surprisingly, they are quite low in cost. To use a binder for screen printing, it must be prepared into a printing paste by the user. To do this, a weighed quantity of raw binder is put inside a bowl or suitable container. About 3 to 6% of pigment ink in a concentrated liquid form is poured in and stirred to obtain the desired depth of color. Fixer is added next in the prescribed percentage, usually 3 or 4%. Other ingredients may be added to modify the properties of the paste, the most important of which is the thickener, used to control its rheology or to put it more simply, the viscosity. Thickener makes the printing paste stiffer and prevents the ink from spreading out by capillary action on cotton articles. After the addition of all these ingredients, the color may have to be adjusted a little. The printing paste must be mixed thoroughly and used within three or four days, during which period it may be stored in airtight containers in a cool, dark place. It is advisable to purchase binders, fixers and thickeners from the same supplier to ensure compatibility in the chemistry and hence avoid unpredictable results.

Readymade printing pastes requiring only the addition of pigments are available but they possess limited shelf life because polymerization occurs even at room temperature due to the presence of the fixer, although the reaction takes place very slowly. Six months can be a long time though and could result in the paste becoming quite stiff and less workable. Regular binder after drying and curing turns into a clear and colorless material with poor hiding power but works well enough when printing on light colored backgrounds. Binder with an opaque white base is used when printing on dark materials as it possesses good hiding power that blocks the underlying color from showing through. A rubbery white binder is also marketed for printing on stretchable materials so it will not crack when the material is pulled. Regular binder will develop a fine network of lines through which the background will show if the material is stretched. Puff binder produces a raised or embossed effect with a rounded profile. Other types of binders and printing pastes are also offered in the market such as those displaying a pearlescent effect and with metallic gold and silver finishes. These binders are rather more expensive than the regular variety.

With a normal printing table, it is feasible to print only on unstitched garments because it cannot deal with more than a single layer of fabric at a time. After printing, the fabric pieces are stripped off the sticky table and hung out to dry on lines in an airy, protected place. When completely dry, the prints need to be heat set to render them permanent and waterproof. Heat setting is normally accomplished by ironing the printed articles with a hot clothes iron on both sides for a total duration of 3 or 4 minutes. The reverse side of the fabric is ironed directly and then the printed side is covered with a piece of cloth and ironed over it. If the iron is applied directly onto the print, streaks of ink will appear on the adjoining areas and stain them, spoiling the work. Fabric printed with emboss effect ink must be kept on a plush cloth surface and ironed on the reverse side to develop the puff effect freely. For maximum puff effect and permanence, heat may be applied onto the printed side as well with a hair dryer. In all cases, a medium or medium-high setting is

kept on the iron. The highest heat setting should be avoided, and the iron kept moving constantly to prevent scorching the fabric. It is also possible to use a commercial drying oven to heat set the inks and speed up production by eliminating the time-consuming labor involved in ironing. During heat setting of inks volatile substances may be released. They can cause eye discomfort to the person doing the ironing and possibly breathing difficulties in persons with a predisposition to respiratory problems.

After heat setting, some unfixed pigment may remain on the fabric. This should be removed by washing the material in running water to prevent it from settling on and coloring other parts of the fabric.

Pigment and binder-based printing is performed using screens coated with water resistant emulsions because this ink system is water based. Polyester fabric with low mesh counts varying from 32 to 62 openings per inch are used because fabrics with higher mesh counts soon clog up with the pigment particles that tend to build up in the openings as the work proceeds. If this happens, an aerosol product called ‘screen opener’ may be sprayed on the screen, allowed to work for some time and the latter wiped clean to get rid of the blockage. Choose the correct type as there are two varieties, one meant for water base inks and the other for solvent base inks. The printing paste also tends to dry up on the screen due to loss of moisture. This problem can be minimized by maintaining the humidity in the printing room above 50% by installing a humidifier. A more economical alternative would be to use a sprayer bottle filled with water to mist the screen at frequent intervals. This ink system works best on multi-filament fibers but is not suitable for printing on wool, silk, nylon and unblended polyester. Thin and tightly woven fabrics require just a light coating of ink to ensure good coverage. Thick and porous fabrics on the other hand call for heavy deposits of ink. It is easy to exercise control over this parameter as the heaviness of the ink deposit can be adjusted by forming the stencil to the required thickness. Puff binders are laid down using a thick stencil as the emboss effect is more pronounced with a heavier deposit of ink. The pigment/ binder system is very popular for textile printing due to its low cost. It can be used only for printing flat color designs. When the work is over, the screens, squeegees and spatulas may be cleaned by washing with tap water, a mild liquid detergent and a soft brush.

The third type of ink used to print on fabrics is plastisol. Generally, inks cure through evaporation of the solvents, reaction with the substrate or oxidation of the vehicle. UV curable inks harden by exposure to ultraviolet light. Plastisol inks differ in that they are cured by the application of heat. This ink medium is composed of a polymer that hardens and turns into a durable plastic like material when heated to about 160~170° Celsius and kept at that temperature for about 35~40 seconds. The machine specially designed for this work is the conveyor dryer, but the flash dryer meant for effecting partial cures when printing multiple colors is frequently enlisted for this work by printers working on tight budgets.

The conveyor dryer is usually a heavy floor-standing unit with a tunnel like chamber heated from above by radiant heating panels. Resistance wires mounted on ceramic supports direct infrared rays onto the printed textiles that move slowly on a conveyor belt from one end of the tunnel to the other. Many dryers are equipped with a blower as well to provide supplemental convection drying for use with other types of ink. The printed articles must be spread out neatly on the belt so that the plastisol ink on them may be cured properly during their slow passage through the tunnel. There is provision for adjusting the belt speed and the height of the inlet and outlet openings by vertical doors. Power rating of the heating elements may range from 2,500 to 11,000 watts. The width of the conveyor belt may range from 20 to 40 inches. Even thick deposits of plastisol ink can be cured effectively because the shorter wavelength infrared rays have a penetrating

quality. Conveyor dryers are generally used to bring about a complete cure of the plastisol ink on printed garments.

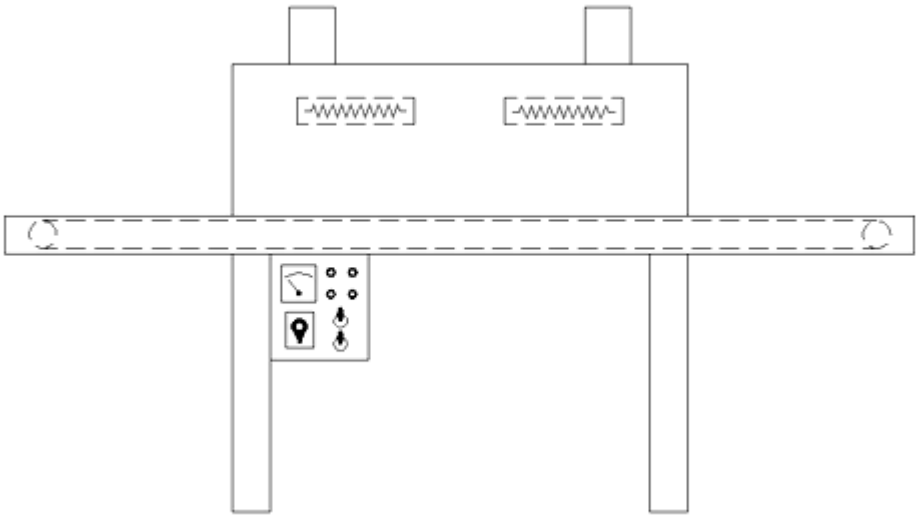

Fig. 19.3 The endless belt and heating panels inside the conveyor dryer are shown as dotted lines.

A flash dryer is also a floor-standing unit, but it is of much lighter construction. It comprises a square or rectangular heating panel that faces downwards and arranged to swivel around on the top of a floor stand so that it can be swung above or away from a printing table on which the article to be heat cured is positioned. This considerably speeds up work when the same garment must be cured repeatedly 'in situ' when doing multicolor printing with plastisol inks because each ink must be cured partially before depositing the next ink to prevent intermingling of the colors. This is known as 'flash curing'. The floor stand is adjustable for height and mounted on a wide base supported on castors to provide mobility around the work area to facilitate operations. Flash dryers can also be used for complete curing of printed articles but are not as efficient as conveyor dryers for this purpose. They have lower power ratings than the latter, usually in the 1,600-to-4,500 watt range. Exercise care when working with the flash dryer as the hot surface is fully exposed.

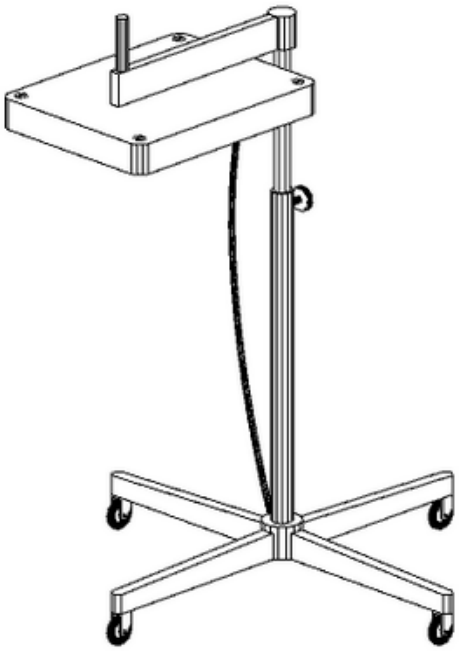

Fig. 19.4 The heating panel of the flash dryer is aimed downwards.

Plastisol inks are easy to work with as they can print through a wide range of mesh counts. Besides, they never dry on the screen while printing is in progress. The inks may even be left overnight on the screen without any fear of blockage due to drying because heat is the only agent that can effect a cure. Plastisol inks may be intermixed freely to obtain any desired color. Various ink additives are also available to obtain such qualities as a suede finish, metallic finish, glitter effect, puff effect, fluorescent and phosphorescent effects. The latest addition is a type of ink with a mirror-like finish. The availability of such a wide range of inks affords many possibilities to the T-shirt printer to produce some very nifty effects. Plastisol inks enable fast throughput of multicolor work because they are amenable to fast heat curing under a flash dryer, typically about 15 seconds per ink for a partial cure that is enough to prevent the colors from mingling together.

These inks are very popular in the U.S. with professional and amateur screen printers for the printing of T-shirts. The traditional approach to decorating T-shirts was to cut the panels first, screen print on a panel and then stitch them together with the rear panel, sleeves and collar. This required collaboration between a garment factory and a screen printing shop with the attendant business and logistical problems because the work in progress had to be shuttled constantly between two separate entities. The alternative solution to this called for large resources and not all parties were able to run both these diverse operations under one roof. This proved to be an awkward constraint that severely hampered activities in this sphere until screen printers figured out a way to decorate on a routine basis, fully stitched, blank T-shirts. This has simplified matters for both parties as screen printers could purchase blank T-shirts from garment factories ex-stock or place an order specifying their requirements. This was easy, as it involved nothing more than a simple buyer/ seller relationship between the parties. There was no need for any special collaboration and a minimum order of three dozen T-shirts could be negotiated. One big risk was involved though; if there was a misprint, it made things awkward for the printer! It is difficult, if not impossible to reclaim fabric misprinted with any type of ink, either before or after curing. Much time can be wasted, and a fair quantity of solvents and chemicals consumed in the process. After removing the misplaced ink, the blank T-shirt could lose its pristine look and take on a shop-soiled appearance. These points need to be taken into consideration because a fully stitched T-shirt is much more costly than a single panel

due to its higher material and labor content. Nevertheless, many printing shops seem willing to take the risk.

Whichever way T-shirts are printed there is one important condition that must be met, and this applies to all textile materials. The work piece must remain on the printing table or pallet until all the inks are laid down and the sequence completed. In the previous chapter, we saw how paper was removed and replaced on the printing table repeatedly to receive each ink. This trick cannot be performed with textiles because they are floppy materials that lack dimensional stability. The carousel printer was therefore devised to overcome such difficulties associated with the production of garments that had to be printed in multiple colors. The carousel printer performs most efficiently when it is employed in conjunction with plastisol inks and a flash dryer.

A simple carousel printer comprises a printing table and four swinging arms, each equipped with a pair of clamps for holding a screen. The printing table is a thick, flat board fastened rigidly to a tubular arm that extends horizontally from a sturdy central column anchored to a heavy base. The swinging arms are spaced 90° apart and pivoted to a hub that can rotate freely about the column on anti-friction bearings. A notch at the head of the printing table engages with a peg on the bottom of each swinging arm, indexing it accurately so that each screen, when it swings down, will come to rest in precisely the same rotational position with respect to the table. The entire assembly, though of a simple configuration is constructed with great mechanical precision to ensure repeatability and tight registration. There is provision for making various adjustments to ensure parallelism between the table and screen including the setting of ‘off contact’. Fine adjustments for registering each screen perfectly by moving it relative to the table are also built into the assembly. This is known as the ‘micro-registration’ feature. A four-station carousel printer is shown in the illustration.

To prepare a carousel printer for production, first coat the printing table with a layer of platen adhesive and allow it to dry until tacky. Swing down an arm and clamp the first screen into the bracket. After eliminating any skew and tilt by making the necessary adjustments, set the ‘off contact’ correctly, with the fabric fixed to the table. Make a print on the test fabric so that the registration marks are also laid down. Bring another arm into position above the table and clamp the second screen lightly onto it. Adjust the position of the screen approximately to align the registration marks on it with the registration marks on the fabric. Clamp the screen tightly and level it. Final registration may be carried out by means of adjustment screws built into the machine. The ‘off contact’ is set last. Repeat the procedure with the third and fourth screens. A selection of registration marks are offered in the print dialog box of most graphics programs. The finer hairline marks are generally chosen for printing on paper and hard surfaces but when printing on textiles it is more appropriate to use a bolder registration mark, which should be burnt into the screens. After all the screens are adjusted to give perfect registration, seal off the marks by taping the screen underneath those locations.

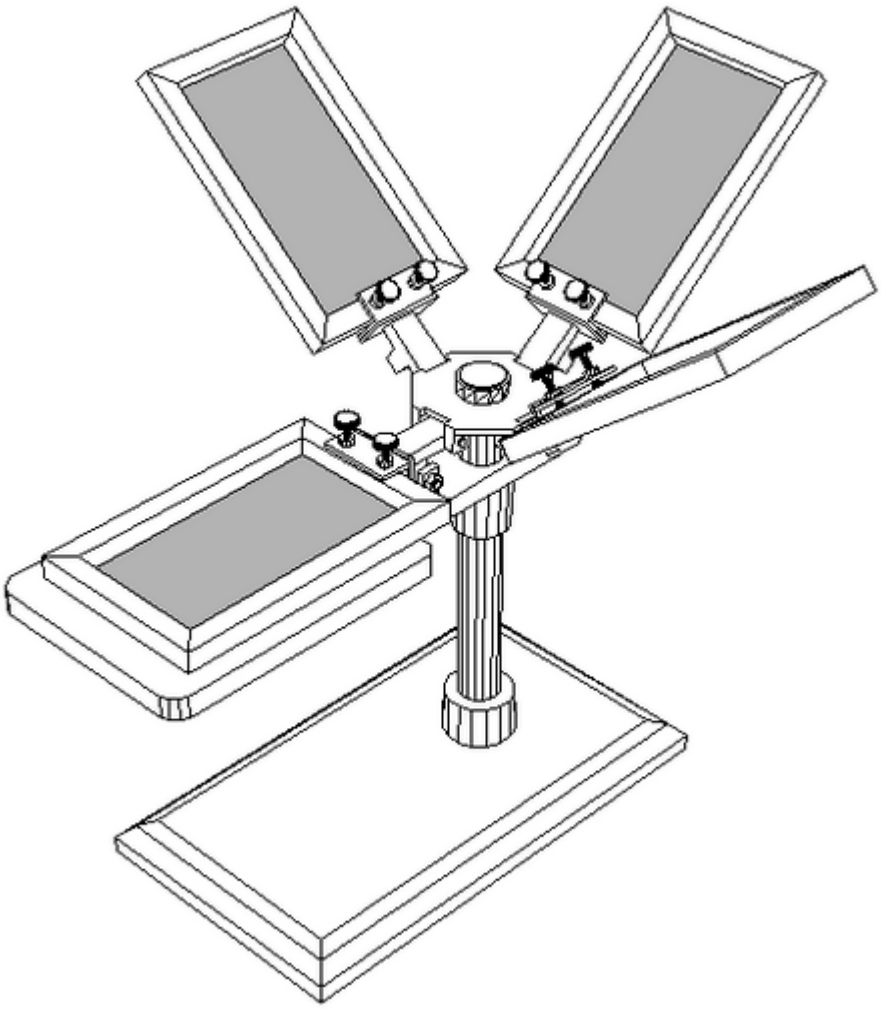

Fig. 19.5 A four-screen, single station carousel printer.

To commence printing, slip the open end of a T-shirt over the printing table and support arm like a sock so that its front panel is above the table and its rear panel below it. After positioning the front panel correctly, smooth out the wrinkles and press down all over so that it sticks to the printing table immovably. The collar of the T-shirt will be closer to you and the image on the screen oriented correctly with respect to the garment, which must remain like this until all the colors are printed and flash cured. Bring the flash dryer alongside the printing table, adjust it for height and switch it on. Then swing the first screen into position over the table and lower it down. Print the first color, raise the screen and swing the heat panel of the flash dryer over the printing table. It must remain in this position from about ten to twenty seconds, depending on various factors. While the ink is curing rotate the carousel and bring the second screen over the table. Swing the heat panel out of the way, lower the screen and lay down the second ink color. Raise the screen and flash cure the second ink to permit the third color to be printed. Repeat the process until the last ink layer is flash cured. Remember that thinner coats and darker colors tend to cure faster than thicker coats and lighter colors.

The result will be a T-shirt printed with four colors of ink that are only partially cured. To ensure proper wash fastness the product should undergo a further heat curing cycle and this is best performed with the aid of a conveyor dryer because it is specially engineered to give a deep cure without scorching the fabric. A flash dryer may also be used in a

pinch to bring about a final cure but would require close attention and control to ensure a complete cure without overheating the ink and the fabric. Excessive heat discolors the fabric and weakens the ink, impairing its permanence. A conveyor dryer is preferable for this work because it improves work efficiency and assures better product quality. Light scorch marks may be removed by treating the affected area with a solution of hydrogen peroxide.

Automatic garment printing machines work on a different principle. These are multi-station units, usually of a circular configuration, with a fixed screen at every station for each color of ink used. The numerous pallets to which the garments are attached move along a conveyor track, engaging in turn with each screen by being raised up and locked in position to receive the ink during the print stroke. The pallets then drop down, ready to move to the next station. There is provision for flash curing each ink after it is put on the garment. In the latest machines this can take place at the printing station itself. In earlier machines there were separate intermediate flash curing stations. A powerful compressor drives several air pistons which actuate the mechanisms that index and maneuver the pallets through the stations while keeping them moving along an endless path. The number of stations can vary from six to eighteen or more. Usually two extra pallets are provided, so that a blank garment can be loaded on one and the printed garment stripped off the other when the rest of the pallets are engaged at the stations. Two operators are required to mind the machine and do the loading and unloading. The printed articles are immediately passed through a conveyor dryer to bring about a complete cure of all the inks used. The automatic garment printer can achieve high rates of output because the printing is mechanized and takes place on multiple screens simultaneously.

Certain important points should be borne in mind when printing with plastisol inks. They must be adjusted to the right viscosity with matched thinners or extenders and should be stirred thoroughly before use to restore their viscosity to a normal level because when kept in storage for long periods they tend to gel and turn viscous. The mere act of stirring can lower their viscosity even without the addition of diluents. If put aside now for a prolonged period, the ink will set once more and must be agitated again to return it to the fluid state. This is known as thixotropic behavior. If further thinning is required, a small quantity of suitable thinner or extender may be mixed in.

You must also use a platen adhesive that can withstand the high heat radiated by a flash dryer; not all adhesives are heatproof. Ensure that the flash dryer has reached its working temperature before you start printing. Some operators even take the precaution of warming up the printing table to the normal working level before they start printing because it tends to warm up as the work progresses, altering the curing speed.

Plastisol ink has poor adhesion to nylon. Yet it is possible to print reliably on this material by mixing in a special nylon-bonding agent to the ink. All ink/ fabric combinations must be tested for wash fastness by putting them through a washing machine with warm water and detergent prior to embarking on any production run. If the inks are not cured well the colors will lighten after laundering the articles multiple times. Garments carrying heavier deposits of ink can tolerate laundering better than those carrying lighter coatings.

When printing light colors on a dark material it may be necessary to give a white or light-colored undercoat first. To do this, all the color areas are combined into a single image and a photopositive prepared from it. A screen exposed through this is used to lay down the undercoat and then the colors are printed over this. Another way to get a solid, opaque image on a dark garment is to print once, flash cure for about 10 seconds and print again.

Next, we need to consider the issue of printing halftones. The fact is, it is just not feasible to print halftone dots directly onto any textile substrate, especially T-shirt material. The fabric is simply too coarse, fibrous and absorbent to permit this. It is possible to do this though, by applying an undercoat of plastic material that will bond strongly to the fabric and form a smooth, coherent, filmy layer. The standard material that is used for this purpose is of course, plastisol ink. White ink is generally preferred for the base coat.

It is thus possible to print halftone images on textile materials, but the resolution cannot be much over 55 lpi. This need not cause much concern because resolutions from about 40 to 60 lpi are quite adequate for this purpose. After all, images on T-shirts are viewed from much greater distances than images on say, books or newsprint and so, at normal distances the dot pattern will not intrude. The screen angle for single color halftone is always fixed at 45°. The mesh count of the screen used for this work should be around three times the line count of the graphic on the photopositive if the dots are to be reproduced accurately. Another point to keep in mind is that elliptical dots give better results when screen printing halftones, especially on textiles.

It is also possible to print process color images on T-shirts using four halftone screens and CMYK ink sets but this is something that should be attempted by more experienced printers. Moiré can be a problem when printing full color continuous tone images. Traditionally, screen angles have been set as follows when printing on textiles.

Cyan = 75°
Magenta = 15°
Yellow = 105°
Black = 45°

Modern screen printers have proposed a different set of screen angles that they claim is more effective at eliminating Moiré. All angles are with reference to 0° denoting due East.

Cyan = 22.5°
Magenta = 82.5°
Yellow = 7.5°
Black = 52.5°

Yellow is usually printed first and black last. If you need to print an undercoat as well, you must use a carousel printer with more than four screens or skip the black ink and obtain a diminished effect.

A modified, yet simple type of table can be used for printing on stitched T-shirts with a single-color ink. The design of this unit can be seen in the drawing below. The gap between the baseboard and the platen allows the garment to be placed in position for printing with the front and rear panels separated to prevent unwanted ink transfer. The off contact is adjusted by keeping spacers of the required thickness between the screen frame and the bottom flanges of the clamps. At the front, rubber pads are fixed under the screen corners. Table glue must be used. Plastisol inks are the safest bet when printing on fully stitched T-shirts.

Instead of printing directly on textiles with plastisol inks, special paper may be employed as a medium to store the image temporarily for subsequent transfer to a fabric material using a heat press. These are known as transfers and are prepared the same way paper and cardboard are screen printed, as explained in the previous chapter. The points of difference are that mirror images are printed on transfer paper with plastisol inks with brief intermediate flash curing stages to keep the ink layers distinct and gelled firmly. The colors are also printed in reverse order starting with black followed by the darker colors,

then the lighter colors and finally the undercoat, if any. Full cure is achieved when the ink deposit is transferred onto the fabric in a special heat press. To do this keep the transfer paper in contact with the fabric and place them between the platens of a hot heat press at a temperature of typically 180° for 20 or 30 seconds. This will be specific to the product so follow the ink supplier's recommendations. The paper used for the transfers is a special type that is treated for easy release once the ink bonds to the textile material permanently. It is usually stocked by plastisol ink suppliers. Peel off the paper gently when everything has cooled down to room temperature.

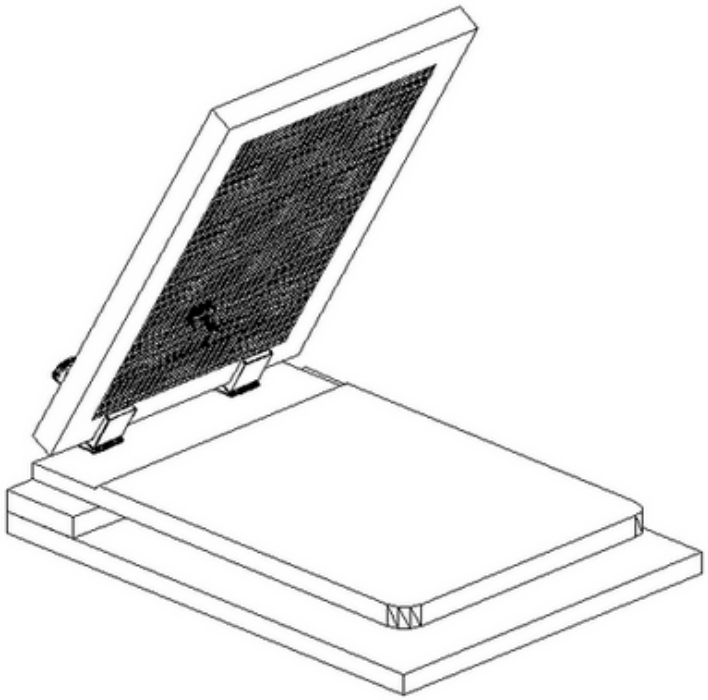

Fig. 19.6 A single color T-shirt printing table with raised platen.

Plastisol printed garments need to be handled with some care. They should never be dry cleaned as the ink, even after curing, cannot resist the action of solvents. Garments should be turned inside out when put in a washing machine to minimize abrasion and erosion. Too much detergent or too hot water is also bad. A hot iron should never be applied directly onto a plastisol print, as it will melt and smear. The fabric should be ironed on the reverse or over a cloth on the printed side at a low heat setting. Fabric care labels must be attached to all plastisol printed garments offered for sale.

The customer's perception of value in a T-shirt is determined both by the quality of the fabric and the sophistication of the decoration on it. A basic aspect of quality is the fiber mass of the fabric material. Some materials are thin, with a loose weave and containing little fiber. They are light in weight, and you can see right through them. There is insufficient material to hold the ink and decorated garments cannot withstand the effects of multiple launderings. Thicker and heavier materials accept and hold ink well, look better and last longer. The point being made here is that the quality of the fabric should be matched evenly to the quality of the print you intend putting on the garment as it does not make much sense otherwise. You also need to consider the quality of the stitching!

Fast drying inks cannot be used with carousel printers because of the relatively long idle times between consecutive print strokes, because each screen has to come round to the

printing platen after making a full circle. The ink will dry on the screen blocking the openings in the meantime. On completion of the print run, the screens and implements must be cleaned using screen wash made for the specific ink. The correct way to dispose of surplus textile printing ink of all types is to soak it up in rags, dry or cure it fully and then incinerate all.

Besides using ink to decorate garments, printers can also coat fabric with flock material to obtain a velvety effect in the image area of any plain material. The powerful screen printable adhesive used for this work is available in a few basic colors. The adhesive color does not have to match that of the flock material precisely as it gets covered fully. A thick coat of adhesive must be laid down and the flock sprinkled on this liberally. The surplus flock is shaken off and collected for reuse. This adhesive dries by oxidation over a period of 12~24 hours and the decorated item need not be put through a drier. It is suitable for fabric woven from natural fibers only as it contains some strong solvents. Stencil compatibility must be checked, and special thinners and screen wash used. It is important to read the Material Safety Data Sheet (MSDS) of this product before working with it.

Chapter 20 – Printing on Various Materials

Apart from pulp and fiber-based substrates, screen printing is done extensively on many other materials. Next to paper products and cotton textiles, wood is the easiest material to print because in common with these two, it has a porous structure that confers very good ink receptive qualities to it. With many wooden surfaces, much of the ink may soak into the pores, leaving little sign of the print. If this happens, a wood sealer or undercoat must be applied by brush prior to screen-printing the surface. A wide range of inks may be used on wood such as oil based, water based, PVC and other solvent-based inks. Then there are also inks made especially for wooden surfaces but sometimes a non-specific ink may serve the purpose better. This is because both natural and re-constituted wood display a great deal of variation in their properties, and they are put to diverse end uses that call for different qualities in the ink. For example, you can choose between hardwood and soft wood, fresh wood and seasoned wood. The printing may be performed parallel to the grain or across the grain. Processed material could be plywood, chipboard or MDF board. The wood may be kept indoors or possibly need to be kept outdoors for long or short periods. The printing may have to be performed on a cheap cigar box or a special gift memento. There is even an ink specially made with non-toxic ingredients for use on children's wooden toys.

Wooden articles received for printing will generally be of much greater thickness than paper, cardboard or textiles. All wooden boxes that come in for printing will naturally be bulky. To deal with such items it will be necessary to modify the printing table and build in a recess or pit to accommodate the workpiece and hold it in the correct position with respect to the screen to receive the ink. Wooden substrates may come in other shapes too and so some means will have to be devised to hold each of them in the correct position to facilitate printing. Drying racks too may have to be of a different configuration.

It is not possible to classify screen printing inks neatly because every type of ink shows an affinity to a different grouping of substrates. Terms such as water-based ink, oil-based ink, solvent ink, silkscreen ink, synthetic ink, dye ink, lacquer ink and enamel ink do not give the slightest clue regarding the materials for which they are intended. Any of these ink types can be used across a wide range of substrates. Just to give you an example, there are different enamel inks for glass and for metal. Then there are matt inks and gloss inks, transparent inks and opaque inks, brittle inks and elastic inks. Many inks are intended for mild environments, and a few are designed for outdoor use. Some inks cure by exposure to UV light. Some inks are known only by some trade name. Therefore, it is best to consult your dealer, study the data sheets of available inks and experiment a little before selecting an ink for a particular substrate and environment.

Metal surfaces may be printed with oil-based inks, synthetic inks and enamel inks. The metal that is screen printed most frequently is aluminum because it is cheap, lightweight and does not corrode under ordinary conditions. Some inks especially made for printing on aluminum are designed to bond well to the tough film of oxide always present on the surface of this metal. Nameplates, labels and data plates for various products and equipment are made by printing on sheet aluminum. All surfaces to be printed must be wiped clean with a rag dipped in denatured alcohol to get rid of all traces of oil, grease, dirt and dust.

Another metal that is often printed is stainless steel. Synthetic, sign enamel, UV and gloss enamel inks prove suitable for this application. Information about the mesh count and type of stencil appropriate for the ink is usually provided in its data sheet. If detailed technical information is not available, you will have to choose your ink based on the limited information furnished by the retailer and gleaned from the label. Many inks that

have poor adhesion to untreated metal will bond reliably if the surface is primed with a lacquer coating first.

Whereas brass can be screen-printed, it is not the ideal candidate for this process. It is too heavy, expensive and the unprinted background is subject to discoloration. A different process, namely etching, is more appropriate for this metal. After etching, the sunken areas are usually covered with ordinary gloss paint. The screen printer still has a role to play though because he must coat the brass sheet with etch resist ink, using his methods!

Printing on glass using ceramic inks is a highly specialized activity that is discussed in Chapter 22. It is much more convenient to print on glass using other types of ink though none of them can match the durability and resistance of ceramic inks. Out of the non-ceramic types, the two component inks are probably the most durable and permanent. These are usually epoxy based. A small quantity of hardener is added to the paint and mixed thoroughly before printing. The pot life is several hours so there will be no compulsion to rush through the work. The printed articles must be stacked carefully on shelves until the ink dries hard, but the screen should be cleaned before the ink dries up, using a special thinner. The drying period may be shortened by curing in an oven and this has the effect of improving the durability of these inks further.

Another type of ink used for printing on glass is based on organic pigments dispersed in a resin that requires heat curing at a temperature of about 200° Celsius. This ink has a much wider color range than ceramic inks and uses much less energy for curing, besides eliminating all risk of breakages during the heating cycle. It is of course not as durable as the ceramic inks fired at high temperature in a kiln.

UV curable inks are also an option. Most of these inks can be used on other substrates too such as metals. When working with same do not install bright lights to illuminate the working area. The printed article is cured by placing it under a mercury vapor lamp for about 30 seconds for the cross-linking reaction to occur and harden the ink. With these inks, it is possible to print images using a rich palette of colors that can last long.

It is also feasible to print on glass surfaces with gloss enamel or synthetic screen ink for low end applications. Fair results may be obtained on glass surfaces not subject to high temperatures, strong chemicals, bright sunlight or scuffing. Even repeated immersion in detergents may be hard on these inks. The surface of the glass should be cleaned thoroughly before printing to ensure good adhesion.

The inks used on glass may be ranked as follows in terms of their physical and chemical properties. Ceramic inks are the best in this respect though they are difficult to process and possess a limited color gamut. Two component inks, heat curing organic inks and UV curable inks perform very well when matched to the conditions of service. These inks are available in a wide range of colors. Gloss enamel screen ink and synthetic ink come last but they are the cheapest and easiest to use. Whatever type of ink is employed, take the trouble to study the product data sheet and carry out a few tests to verify its suitability for the end use.

Metal and glass are hard, impermeable materials. If they also happen to possess a flat and smooth finish, they present the ideal surface for printing. A high-resolution image may be printed easily with UV ink using a hard, sharp-edged squeegee. For process color images, the registration must be spot on. If the print is to be viewed through the glass, the image must be reversed on the photopositive. Metal and glass are very much thicker than paper and therefore the registration stops should be of corresponding thickness, that is, slightly less than the workpiece. When printing on thick substrates the entire area traversed by the squeegee blade needs to be at the same level. It is therefore necessary

to surround the work piece with a border of the same height to ensure a smooth passage for the squeegee over the full area swept by it. The surround can also serve as a sort of registration stop to locate the work pieces in the correct position but since there will be some clearance to allow for slight variations in size, they must be pushed against the same corner every time so that all the work pieces may be printed in a like manner.

Purpose-built machines are available for screen printing on the curved surfaces of glass bottles. The machine is equipped with the necessary adjustments to accommodate bottles of different diameters and lengths. The smaller and lighter screen frames fitted to the machine are designed to move with a reciprocating action under the stationary squeegee. The glass bottle positioned below the screen and aligned under the edge of the squeegee rotates in step with the movement of the screen to receive the print. The precision made screen carries a nylon mesh as this material is more elastic than polyester and hence is able to adapt itself to any unevenness on the bottle. 'Off contact' is an essential feature on this type of machine too. The work pieces must be loaded and unloaded manually. Bottle printing machines are quite complicated in design and so will have to be purchased from a specialist supplier.

Substrates made of various other materials such as fiber, rubber, coated fabrics and even leather may be printed using suitable inks. When printing on unusual surfaces remember that an ink that dries into a rigid coating should not be used on a soft substrate. Likewise, ink made for soft materials may not hold onto a hard surface.

Balloons are decorated predominantly by screen printing. Specialized latex-based inks are used as normal balloons are made of latex rubber. The balloon is inflated to 75~80% of capacity, the neck clamped with a rubber lipped clip, then placed in a pit with part of it projecting out. The shape of this pit is not critical. As the screen is lowered and pressed down, the exposed surface gets flattened. There is no off contact here. The printing is done next, the balloon deflated and placed for a few minutes in a heated dryer maintained at the correct temperature. As the material of the balloon is soft and thin it is very vulnerable to the action of solvents and other chemicals present in most inks. Failure usually occurs just as the customer is inflating it! Therefore, it is necessary to emphasize the importance of selecting tailor-made inks for this application. Some people may consider balloon printing to be a somewhat frivolous occupation but there is money to be made here.

When it is desired to cover a flat area with a uniform coating of paint, adhesive or any other medium, a blank screen will work admirably for this purpose. A fine mesh will yield a thin coat and a coarse mesh, a thick coat. The boundaries may be defined sharply by applying frame tape along the four sides of the screen on its lower surface. Adhesives designed for application by screening are available commercially, both in water based and solvent based formulations. These products are viscous liquids, and it is possible to adjust their properties by mixing in various additives. Use a squeegee with a rounded edge profile when screening adhesives to get good coverage. Substrates that will be adhered later, such as stickers, must be heat cured for a period after applying the adhesive for it to develop the right degree of tackiness and then covered with wax or silicone coated release paper.

Open screens are used in the manufacture of products of layered construction. Specialized materials are applied as thin and even coatings on substrates with curing stages in between. Only the borders are defined in these screens and the coating thicknesses are controlled within narrow limits. Two high-tech examples are electroluminescent panels and photovoltaic cells. Thus, it will be seen that even a blank screen can prove itself a useful production tool on the factory floor.

Chapter 21 – Printing on Plastics

Next to paper and textiles the most widely screen-printed materials are plastics. As you will be aware, there is an enormous range of plastics, also known as polymers, which possess widely varying physical and chemical properties. For this reason, the ink receptive qualities of plastics turn out to be highly specific so that an ink that bonds very strongly to one type of polymer might react to another polymer as though it were a non-stick material. Of the plastics, vinyl possess the most ink receptive surface and so many solvent based inks can be used to print on them. Most other rigid plastics too have good ink receptive surfaces. Polyethylene (a.k.a. polythene) and polypropylene are not easy to print on, requiring pre-treatment and special inks. *Nylon* and *Delrin* are difficult to print while *Teflon* (PTFE) defies all such attempts.

Many hard plastics such as polystyrene, acrylics, polycarbonate, PET and co-polymers like ABS may be printed reliably with either gloss enamel inks or what are known as all purpose screen ink. PVC plastics are available in rigid and flexible forms, and both may be printed with vinyl inks. Except for vinyl ink, it is not possible to guess from the name of an ink, the type of substrate for which it is intended. Therefore, before purchasing ink for printing on any plastics material, study the technical data sheets of suitable products carefully. When you do peruse the information provided, you may come across a notice such as the following that appears in small print.

"While technical information and advice on the use of this product is provided in good faith, the User bears sole responsibility for selecting the appropriate product for his end use requirements. See full disclaimer below."

The reason for putting this notice is that in addition to the wide range of distinct plastics there are such things as plastic alloys, co-polymers, re-cycled plastics, etc. with widely varying properties. Even the same polymer may be available with differing molecular weights and correspondingly variable characteristics. Some plastics are compounded with UV stabilizers or plasticizers while other types may contain antistatic agents or flame retardants. The composition of screen-printing inks may also show equal diversity. Many of them are proprietary products that must be used with specified auxiliaries obtained from the same supplier. To confound matters further, screen printing inks generally have names that do not give any hint as to their end use. For these reasons, it is not a simple matter to match the ink to the substrate. Therefore, it would be prudent to test the ink on the material before stocking up and commencing a long production run.

The screen printing of PVC stickers can be an easy, interesting and profitable occupation. Adhesive coated flexible PVC film mounted on release paper is available in white and other background colors. The material is available with a gloss or matt finish. The printing is performed with PVC ink using a solvent resistant stencil. Often, a special additive known as a Reducer is added to control the viscosity of the ink. If the ink dries too fast, then that too can cause problems by blocking the openings of the mesh. An additive called a Retarder is mixed into the ink to overcome this problem. Do not confuse the two as these additives perform different functions; the reducer adjusts the viscosity by thinning the ink and the retarder increases the working time by slowing down the drying process. PVC Reducer and PVC Retarder can be used with both PVC inks and what are known as S/S inks. PVC thinner is used to clean up everything when the work is over. Printing stickers may be performed on the same setup that is used for paper printing. Most stickers are printed in multicolor while four-color process printing is also possible. The registration procedures are the same as for paper. Small stickers may be arrayed in a grid pattern and printed on the same sheet in large numbers. After drying, the stickers may be cut out with a paper cutter or scissors depending on the shape of their outlines.

The sticker may be pasted onto any dry, even surface after peeling off the backing. The product has good waterproof qualities.

PVC stickers also come in a transparent form, and this is marketed in two versions. One is suitable for pasting onto any smooth surface where the background color must show through. The other is designed for pasting onto the inside surfaces of windscreens and windows and is meant to be viewed from the outside. The matter put on the positive must be reversed if the image on the 'inside pasting' sticker is to appear correctly oriented when viewed through the glass. When printing process color, black is printed first followed by cyan, magenta and yellow. If necessary, a colored or white background may be printed last on this type of sticker.

It is possible to make your own stickers on metallized plastic foil or other thin plastic film. To do this, print the arrayed matter on the shiny side with PVC ink. When the ink dries, coat adhesive through a screen onto the matt side. After allowing the adhesive to air dry in a warm place for about half an hour cover with a sheet of release paper. You must use the type of adhesive that dries to form a tacky coating.

Printing on flat plastic surfaces is a straightforward operation. A smooth plastic surface can be printed on at a much higher resolution than paper or boxboard. The mesh count chosen should be between 2¾ to 3¼ times the print resolution measured in dots per inch, depending on the quality desired. Naturally, rigid plastics may be printed on at a higher resolution than flexible sheets. Solvent inks are generally used, with PVC ink being the most used variety. Reducer and retarder may be mixed in thoroughly as desired before beginning the printing operation. These types of ink generally dry fast so the screen and implements must be cleaned up immediately upon completion of the production run. If ink is left to dry on the screen, then removal can become very difficult.

The screen printing of plastic bottles and other items of a cylindrical shape can be a profitable activity, but this requires a purpose-built machine that is of rather complex design and construction. If it is feasible to make such an investment, the machine will prove itself to be an asset. These machines come in a wide range of sizes and production capacities with matching price tags. Every machine will be able to accommodate a range of bottle diameters and lengths. Once the machine is in place, the screens can be made in house.

As mentioned earlier, low density polyethylene (LDPE), high density polyethylene (HDPE) and polypropylene (PP) must be pre-treated to render their surfaces receptive to ink. These materials possess ink repellent surfaces and the so the ink cannot wet them or cling to them as a thin film. This phenomenon is due to these types of plastics having a low surface energy, which is measured as surface tension, causing the ink to form beads on their surfaces without spreading out and wetting them. Surface tension is readily observed in liquids but not in solids, though the latter too can possess energy by virtue of presenting a surface. PE and PP have a low surface tension of about 30 dynes/cm that needs to be increased to around 40 dynes/cm to achieve satisfactory ink adhesion. This is the purpose of pre-treatment, as the surface tension of the substrate has to be greater than that of the ink. Water splashed onto an untreated PE or PP container will bead up and drip off without wetting its surface but will wet the surface of a treated container, forming a thin film on it, which soon evaporates.

Flame treatment is the most popular process for increasing the surface energy of plastics so that they may print reliably. Flame treatment machines are available for preparing plastics containers to be printed. A series of burner nozzles are arranged in a row with fine adjustments for adjusting the flame. Propane, butane or any other hydrocarbon gas may be used to give an oxidizing flame of a deep blue color. The container is loaded

manually onto a rotating mandrel that is advanced towards the flame and retracted after a brief interval. The container is automatically unloaded and dropped into a bin. There is provision to accommodate different size containers. The period of exposure to the flame should be just right because if it is too short the pre-treatment will be inadequate and if too long, the plastic will distort. Adjustment of the flame is very critical too. It is not so much the heat that causes the change in the surface of the plastic but the oxidizing effect of the flame. Therefore, simply heating the plastic will not result in any change in its properties. After treatment, the article must not be touched with bare hands. Wear suitable gloves and handle it by the non-printing surfaces.

The effects of flame treatment can dissipate after some time, so it is best to perform this operation just before printing. Test kits are available for assessing the surface tension of treated surfaces. A cotton swab is dipped in a liquid and applied on the surface to be tested. It is possible to get a reasonably accurate measurement of the surface tension in dynes/cm from the way the test fluid spreads itself on the material. The test kits are made up of a set of liquids of specified surface tensions and are supplied with detailed instructions for use. The test kit gives valid readings whatever the method of pre-treatment employed.

Applying a liquid primer is an approach that works well for some waxy plastics, such as polypropylene. It does not work so well for polyethylene. The liquid primer is corrosive and is rather hazardous to use. Skin contact and inhalation of the vapors should be avoided. Treatment is by means of dipping or spraying. The products from different suppliers do not have the same properties or exhibit the same performance. Sometimes a product may yield varying results with different batches of what is essentially the same plastics material.

Another method of pre-treating these plastics is to use an electrical device known as a corona discharge unit. A high frequency, high voltage current is made to pass through the plastic, causing certain changes to its surfaces and this has the same effect as the flame treatment method. High frequency electricity tends to travel over the peripheral areas rather than through the main body of a material, resulting in a large current flow just under and on the surfaces. This is known as the ‘skin effect’. It is the large current flow over the surface of the plastic that brings about the increase in the surface tension. This way of treating plastics is most suitable for blown films as they are of thin section and are produced on a continuous production line into which the corona discharge unit can be neatly integrated. The equipment does not require a warmup period and can be switched on and off rapidly. The corona discharge method does not distort the articles as much as the flame process so that it is more suitable for heat sensitive plastics. Now it is also used to treat thick and hollow items by means of specially developed equipment. The corona discharge process generates toxic ozone gas due to the high voltage used, requiring some provision for exhausting it safely. The humidity may need to be controlled in the operating environment and another disadvantage of this method is that it is only viable for production on a larger scale.

Some PE and PP inks are two component products and there are UV curable inks too for printing onto these surfaces. The printing may be performed in the usual manner with these inks immediately after the pre-treatment. The materials and techniques for printing on plastics are constantly evolving just as in all other areas of screen printing.

Chapter 22 – Ceramic and Glass Transfers

Printing on glass with ceramic inks is a specialized operation. In theory, it is possible to print directly on glass surfaces with ceramic inks, using a screen. These inks consist of colored glass that has been ground into a fine powder known as frit. The coloring agents in glass frit are the oxides of metals such as antimony, chromium, cobalt, copper, iron, manganese, nickel, and vanadium. Cadmium sulphide and cadmium selenide are also used for this purpose. The compounds of many other elements such as gold, silver, indium, and uranium too are able to color glass but are not much used due to their high cost or restricted supply. The ceramic ink may be purchased in powder form together with the mixing medium or in a more convenient paste form. These inks usually appear dull and drab with colors bearing little resemblance to the hues that would show up after firing them in a furnace. Ceramic inks develop their full brilliance and colors only after combining with the silicates in the glass, and this can occur only when the printed glass is fired at a bright red heat. This drastic action causes the ceramic ink to react with and fuse onto the surface of the glass, forming a hard and durable image that possesses excellent resistance to abrasion, detergents, and many chemicals. Drinking glasses, glass bottles and decorative glassware are commonly printed this way.

Ceramic inks can be used on glazed porcelain such as dinner sets, tea sets, mugs, wall tiles, sanitary ware etc. The glassy covering on glazed porcelain has a composition similar to that of glass, so ceramic inks can work on these products equally well. Glass is fired at temperatures of 600° to 700° Celsius to fix the ink but porcelain ware is fired to a higher temperature in the region of 1000° to 1100° Celsius. As these products need to be fired at different temperatures to fix the color, ceramic inks are also made with the appropriate properties. Therefore, always select the ink to match the type of substrate and the firing temperature. Incidentally, the furnace used for heating glassware is referred to as a lehr and the one used with porcelain and pottery is called a kiln.

Lehrs are designed to anneal glassware by heating them almost to the softening temperature and then cooling slowly in order to get rid of all internal stresses built up by the rapid heating and cooling cycles encountered during the manufacturing stage. Annealed glass is less likely to break in service than untreated glass. Lehrs are also used to fire glassware that has been printed with ceramic inks. Kilns are used to fire the molded china clay into porcelain ware, fire the glaze onto it and fire the ware again after it has been decorated with ceramic inks. Lehrs and kilns are usually gas fired but sometimes they are heated electrically by means of resistance wires. It is possible to exercise greater control when heating with gas because the atmosphere in the furnace chamber can be adjusted as desired to influence the final color obtained with some inks. With an oxidizing atmosphere, the higher oxides will impart color but with a reducing atmosphere, the lower oxides will form and produce a different color. The atmosphere in the firing chamber is controlled by adjusting the dampers to increase or decrease the airflow while holding the gas flow constant. The chamber atmosphere in an electric kiln is normally oxidizing but it is possible to transform it to a reducing state by introducing carbonaceous materials inside. However, resorting to this technique on a regular basis will shorten the life of the heating elements drastically because the powerful reducing atmosphere will try to break down the protective oxide coating on them.

It is feasible to perform direct printing on glassware only in a large glass factory that has its own screen-printing sub-unit equipped with specialized machines for printing on curved and irregular surfaces. The capital investment needed to put up such a factory may be a hundred times greater than that required to start a small screen-printing outfit. Moreover, the firing of glassware is a risky operation as there is always the likelihood of deformation and breakages resulting in rejections. For these reasons, it is difficult for the

small screen-printing shop to perform direct printing operations on glassware. It is not practical either to shuttle glassware between a glass factory and a printing shop because glassware can hardly tolerate any handling between the printing and firing stages. There are other reasons too. Therefore, it would seem there is hardly any scope for the screen printer to practice his art and put his creative ideas on glassware or ceramic products.

Fortunately, despite all these constraints, it is yet possible for the small-scale printer to work in this field and make a profit by producing and supplying ceramic transfers for use on glassware and porcelain ware.

These are printed with ceramic inks on slightly porous paper stock coated with a water-soluble gum like layer. Once the ink has dried, a special cover coat is put over the paper and as it dries, it bonds fast to the ink, sealing it in. Usually several images, which may be identical or different, are screen printed on large sheets of decal paper. After cutting out each transfer with scissors, it is soaked in water for about 30 or 40 seconds. Water penetrates the porous backing and partially dissolves the gum. It is now possible to slide off the transparent layer of hardened cover coat carrying the ink off the paper and transfer it to the glass or ceramic surface. After smoothing it in place and allowing it to dry overnight the ware can be fired. The cover coat and the ink medium burn off, leaving the ceramic ink in place, which reacts with and becomes part of the substrate. These ceramic transfers are popularly known as water-slide decals because the transparent layer can be slid off and separated from the backing paper after immersion in water.

It is much easier to practice ceramic printing on glass and porcelain by using transfers than by printing on them directly. As mentioned earlier, the complexities of printing on irregular shapes can be sidestepped neatly by printing on flat paper stock that could later be shaped to conform to the contour of the substrate, within limits of course. It is much easier to achieve accurate registration when printing multiple colors on paper than on variously shaped glass objects. It is also possible to print several transfers on the same sheet of paper at the same time, thereby speeding up production. Finally, this approach enables two specialist firms working on different product lines to form an uncomplicated business relationship to their mutual benefit.

Decal paper, as it is called, is made of slightly porous paper on which a layer of water soluble adhesive is deposited. Traditionally, dextrin was the preferred adhesive, but newer materials are being used by some manufacturers now. It is possible to make decal paper in the screen-printing shop itself if you can find the right kind of paper and the right kind of adhesive. Dextrin gum, which is viscous, is preferable but if this is not available, some other water-based screen-printable adhesive may be used. The paper to be coated is kept on the printing table and the adhesive is deposited in an even layer through an open screen bordered with frame tape. The paper may tend to curl up while drying so it may be necessary to weigh it down by its edges. This can prove to be a cumbersome exercise. Therefore, if you do not mind this sort of thing, you can make your own decal paper, if not you have the option of purchasing and using the commercial product.

The printing is done on the decal paper by laying down the ceramic ink through a screen. As these decals are small, dozens of them can be printed on the same sheet of paper. The decals on a sheet need not be identical. Several colors may be printed, using a different screen for each color. Remember to include registration marks when printing the positives. If the frit and the medium were purchased separately, they must be mixed thoroughly to the correct consistency. Ceramic ink in paste form may be used straight but can be adjusted with mineral turpentine or the recommended thinner if necessary. Each print must dry fully before applying the next color. The glass frit in the ink is made of fine particles that may clog up the openings of the mesh after some time. If this happens, clean and wipe both sides of the screen with a soft rag dipped in mineral turpentine

without removing it from the clamps. Choose the mesh count of the screen in accordance with the ceramic ink supplier's recommendations. When all the colors have been laid down, the decal sheets must be placed on racks to dry completely. The same setup used for printing on thick paper will work equally well for decal paper. The registration techniques too, are similar.

The last step involved in the production of water-slide transfers is the application of what is known as the cover coat. This is a viscous liquid that can be brushed on if necessary but is better applied through an open screen with a squeegee. Using a screen is very much faster and yields an even coating. The ceramic ink does not form a strong bond with the gum coating on the decal paper as the former is based on a non-aqueous medium and the latter on an aqueous medium. The cover coat, however, is based on the same type of medium as the ink, so as the cover coat dries, the ink bonds to it strongly. After applying the cover coat, the decal paper is put aside to dry. Commercial decal paper is designed to resist curling, but this is not guaranteed. Acrylic lacquer sold in aerosol cans works like cover coat and could therefore serve for experimental and short run work. This product is known in the trade as clear coat lacquer and sometimes as overcoat lacquer. It works best when sprayed on as two or three thin coats rather than as a single thick coat. Its disadvantages are that it is costlier and releases a great deal of unhealthy fumes during application.

Cover coat material is sometimes colored with dye to make the layer clearly visible to confirm coverage. The dye does not detract from the quality of the work as it burns off during firing. Stacking cover coated decal paper may cause all the sheets to stick together because sometimes the cover coat continues to remain tacky even after drying for several days. It may be necessary to interleave the sheets with wax paper or very thin plastic film and store them vertically to prevent compaction. Decal paper is also sensitive to humidity, both before and after printing. If it is to remain for any length of time in an environment, it must be given sufficient time to adjust to it due to its tendency to expand or contract, which can cause problems with registration when printing multiple colors. The humidity in the printing room should be maintained at a constant level if possible.

The screen and other implements must be cleaned using thinner soon after this work is finished. As the colorant in ceramic inks is ground glass, it acts as an efficient abrasive that rapidly wears out the stencil material as well as the mesh. Glass frit contains a wide variety of toxic and heavy metals and sometimes it is possible to guess their identities from the color. Though all these metals are locked into the chemical structure of the glass in the form of insoluble silicates, it would still be prudent to handle them with caution. Reaction with acids or alkalis could leach out the metals, converting them into a soluble form in which they could prove toxic.

The printing of ceramic waterslide decals should be undertaken only after acquiring sufficient experience in general screen-printing work. Much experimentation would be needed to get the colors right because the shades obtained after firing may differ considerably from that of the inks used. If you intend to print these decals, you will have to buy a small electric kiln to conduct test firings. A laboratory furnace may prove ideal for this purpose. The kiln should be equipped with an energy regulator, thermocouple, and pyrometer to ensure accurate temperature control, as they are essential for obtaining repeatable results. After printing a decal, the colors can be 'proofed' only after transferring it to a flat glass sheet or ceramic wall tile and firing in the kiln. The illustration below shows a medium size electric kiln used in small pottery workshops for firing ceramic ware. These shops obtain the ceramic decals from outside suppliers.

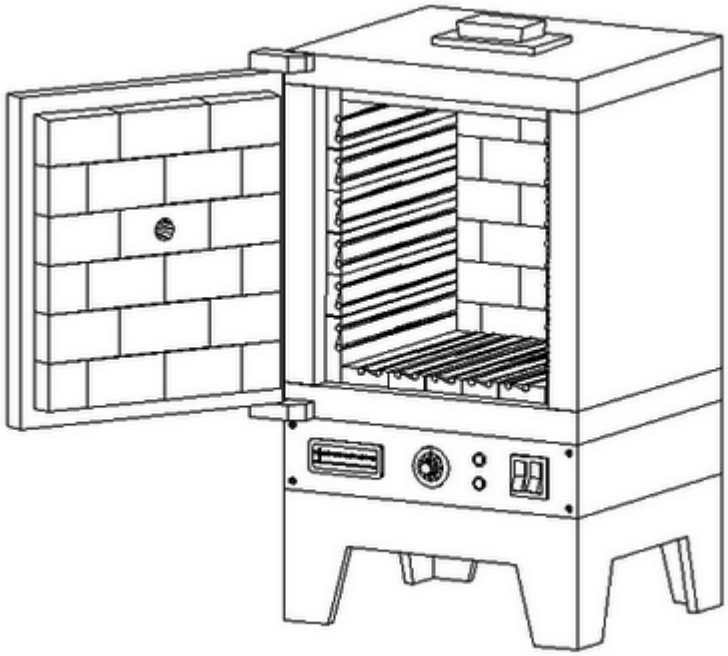

Fig. 22.1 An electric kiln is ideal for firing decorated ceramic ware and glass.

The decals on finished sheets must be cut out by hand with scissors, following their outlines and leaving a small margin around each. To apply each decal onto the glass or ceramic item, you must put the decal in water and soak it for about 30 or 40 seconds, maybe longer. Water will penetrate the porous paper backing and partially dissolve the layer of gum permitting the cover coat layer to slide off freely. The ceramic ink forming the image, having switched its allegiance from the coating of gum to the cover coat layer will be firmly embedded in the latter. The paper backing may now be removed leaving a continuous film of material that holds the image together. This film is fragile and must be handled delicately. The most efficient way to transfer this is to shift it slightly to expose a small area and attach it to the substrate at the desired location. Then slide the backing paper out while pressing down lightly on the film. The substrate should be wetted lightly before applying the transfer so that the latter may slide freely without sticking to facilitate accurate positioning. Use a small rubber pad to squeegee away surplus water and any air bubbles trapped under it. Then use a soft pad to press it into intimate contact with the surface below across its full area. The decal will adhere well to the substrate, as there will be a residual layer of gum under it. The decorated article should be set aside to dry overnight to remove all traces of moisture. Any areas where perfect contact between the substrate and the transfer did not occur will not be printed later, leaving blank spots!

Now comes the interesting part and that is the firing. On firing, the organic ink medium and the cover coat burn off, leaving the inorganic pigments behind. These fuse onto the surface of the glassware or ceramic ware, combining chemically with it, forming a very resistant deposit that constitutes the image. In small pottery workshops, electric kilns are used to fire the green ware, the glazed ware and the decorated ware in three stages to produce the finished article. Let us see how the last operation is performed, as we are only concerned with that. The decorated ceramic wares are stacked carefully on refractory shelves supported by props inside the kiln and the door closed. The heat is raised slowly to ensure uniform expansion of the articles to avoid cracking, held at the prescribed peak temperature for about ten minutes and allowed to cool slowly by shutting down the kiln. The door is opened only when the kiln has cooled down to nearly room

temperature. In practice, it takes longer for the kiln to cool down than to heat up! The whole cycle may last several hours. The heat inside is judged by viewing the color inside the kiln through a spy hole in the door or more accurately by means of a thermocouple placed inside connected to a pyrometer mounted outside. The kiln will have a vent at the top. This is connected to a duct that discharges all smoke and vapors generated during firing to the exterior of the building. The metal compounds present in ceramic inks can volatilize, giving rise to highly toxic fumes when subjected to the intense heat of firing.

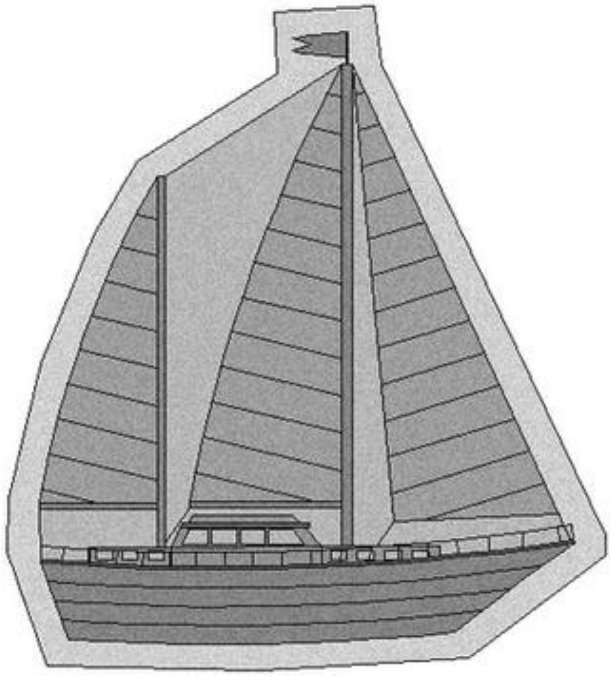

Fig. 22.2 A ceramic decal cut to shape, ready to be transferred to the ware.

Large factories may conduct the firing in continuous kilns, also known as tunnel kilns (lehrs in the case of glass), in which the ware is loaded on trolleys or a conveyor and passed through a very long chamber equipped with a pre-heating zone, firing zone and cooling zone. The temperature gradients in the kiln or lehr are controlled very closely. The heat is raised gradually, maintained at the peak level in the middle and then decreased gradually. The wares enter the tunnel at one end and emerge at the other end after passing through the middle zone that is kept at a bright yellow heat for ceramic ware and a red heat for glassware. The trolleys or conveyor move from one end of the tunnel to the other end very slowly. These kilns are usually gas fired and may work continuously around the clock.

Even if you intend to restrict your activities simply to the production of waterslide decals for sale to outside parties, it is still important to possess a modicum of knowledge about the rest of the operations that must be conducted down the line. You will need to know how the decals are transferred onto the wares and possess some knowledge about the equipment and techniques involved in firing the ink. That is why much information not directly connected to screen printing is given in this chapter.

The making of ceramic decals calls for close collaboration between the supplier and the purchaser. Testing is necessary at every stage of production including the final firing stage that must be performed on sample glass or ceramic ware extracted from the production lot. The colors obtained from the same batch of decals may vary according to

the composition of the substrate. For example, the same decal may appear in different colors on soda glass, potash glass, lead glass and borosilicate glass. In any case, the range of colors that can be obtained with ceramic frits is more limited than that available from all other types of ink, which do not have to undergo the ordeal of being fired in a furnace! Ceramic inks do possess an advantage in that they can produce lustrous metallic finishes on porcelain and glass. This is achieved by using a strong reducing atmosphere in the firing chamber that removes all oxygen from certain metal oxides, leaving the pure metals behind.

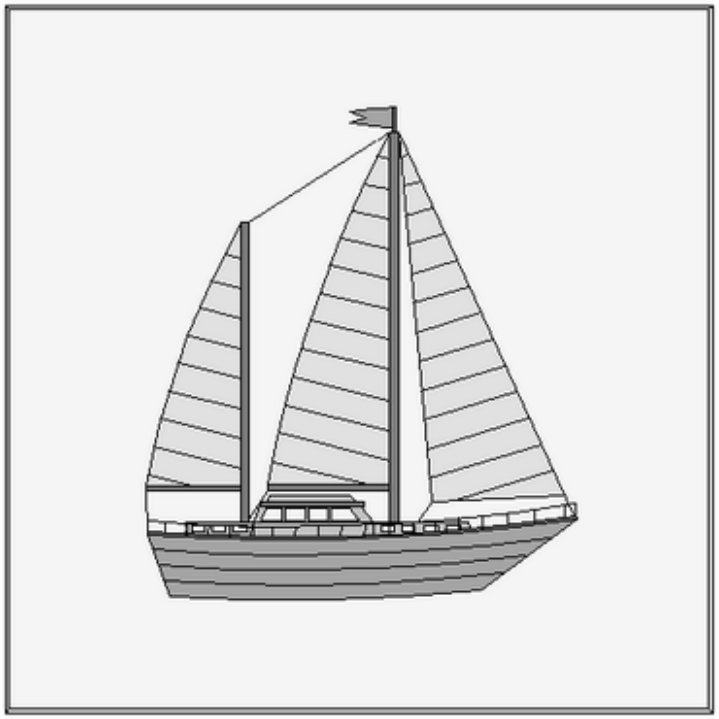

Fig. 22.3 The decorated ceramic wall tile after the firing.

Screens made of stainless steel mesh are frequently used for printing ceramic transfers, but these must be handled with care, as they are susceptible to denting. Once formed, it is difficult to remove the dents. Ceramic inks, decal paper and cover coat are usually stocked by the same supplier. These may be available from the larger screen-printing supply houses or from pottery and ceramic materials suppliers.

Chapter 23 – Etch Resist Technique

Etch resist inks differ functionally from all other screen-printing inks in one important respect. They remain on the printed surface for only a brief period because once they have served their purpose they are stripped off, leaving no trace of their presence. The ink merely serves as an agent performing a temporary role in the production process. These inks are used in the manufacture of printed circuit boards and items such as metal labels, badges and nameplates. All these products must undergo an etching operation in a strong acid bath on their way to becoming finished products. Etching must be performed selectively on these items, meaning that only a part of their surfaces can be exposed to the action of the etching medium. The only way to accomplish this is by protecting the remaining areas from the acid bath by covering them with etch resist ink. To do this the respective surfaces have to be defined clearly. The traditional and still common way of doing this is by screen printing.

Etch resist inks must fulfill many requirements. They must be easy to print and quick to dry. Inks must adhere well to the substrate, provide perfect coverage over the protected areas that must not be exposed to the action of the corrosive etching fluid. The ink itself, once dried or cured, should possess great resistance to the action of strong chemicals but at the end of the work must strip off easily using a solvent or special solution. These requirements naturally call for a product with characteristics that are markedly different from those of conventional decorative inks.

Let us first consider the procedures involved in the production of printed circuit boards or PCBs for short. There is hardly any electronic device that is not based on a PCB. Many devices contain more than one board. All of these boards started as epoxy, polyester or phenolic impregnated glass fiber composites with a thin layer of copper on one or both sides. The copper cladding is performed under heat and pressure during manufacture and thus it is inseparably bonded to the core material. The copper layer has high electrical conductivity whereas the base material acts as a perfect insulator. Blank PCB laminates may be purchased in bulk from specialist suppliers. The thickness of the copper layer may be specified to match the current handling requirements of the circuitry. The boards are marketed in several grades and types. Let us see how a single sided board is processed.

The electronic components such as transistors, capacitors, resistors, diodes, etc. are mounted on the printed circuit board with the copper cladding itself serving as the conductor and connecting these devices together. For this to work, the copper cladding will have to be transformed from a bare expanse of metal into an intricate network of tracks or traces, terminating in pads onto which the components can be mounted. Holes are drilled through the pads into which the leads of the components can be inserted and soldered. Modern mass produced boards use surface mount device (SMD) technology in which the components are soldered directly onto the pads so there is no need to drill holes on the board. The current passes through metal caps bonded to both ends of the component. It is not easy to design a printed circuit board because the tracks must be routed without intersecting each other. In addition, with SMD technology, the sizes and spacing of the pads must be matched perfectly to the dimensions of the components!

Therefore, it follows that the screen printer’s role must be limited to making the screen, printing on the blank boards with etch resist ink and etching them. It is the responsibility of the PCB designer to prepare a high-resolution digital image file of the circuit diagram and other features and provide a copy of it to the printer. Black would represent the copper covered areas, and the white background, the areas to be etched. A photopositive is prepared from this image file, after fixing the size accurately by making a few trial prints

on paper. The size of the printed image can be adjusted as desired in the print output dialog box. The higher the component density and track density the greater will be the demands placed on accuracy at every stage of manufacture. Stainless steel mesh is used routinely for etch resist work on printed circuit boards in the quest to achieve the highest possible accuracy.

Mesh counts of up to 325 threads per inch are used for printing on the boards with etch resist ink but there is a limit to the resolution that can be achieved with screens. Therefore, for fine work with narrow, closely spaced tracks, photosensitive etch resist material is coated directly onto the board and exposed to UV light through a photopositive to harden it over the areas above the traces, followed by developing, hardening and closely controlled etching.

Boards designed for medium component density can be easily processed by making use of standard etch resist inks deposited through a screen.

The blanks should first be cut to the exact size and the edges trimmed or sanded neatly. The copper surfaces are then prepared by rubbing with steel wool or a fine grit abrasive scrubbing pad under wet conditions, washed and dried. This is to get rid of any oxide coating, oil, grease, and other contaminants as their presence would impair ink adhesion. From then on, the boards must be handled by their edges. The printing table is fitted with an array of pits of a depth equal to the thickness of the blanks. The pits are sized to locate the boards accurately with the surrounding material offering a level path for the squeegee. The registration and 'off contact' must be set properly as always. A hard squeegee blade with a sharp edge is a prerequisite for work involving printed circuit boards.

One type of etch resist ink is black in color. After drying normally, this ink will withstand the action of milder etching fluids without further processing. If strong etching fluids are to be used, it may be necessary to cure the ink at a low heat in an oven to toughen it. The ink must be handled with caution and the user is advised to wear eye protection and gloves. Proper ventilation must be provided during printing and when heat curing. This ink can be adjusted like PVC ink with a specific reducer and retarder. Another type of etch resist ink designed for PCBs is a UV curable formulation. It is blue in color. The printing is carried out with care because the best results will be obtained with just a single pass of the squeegee. Either ink may be put on the screen, a little at a time without excessive flooding. Boards printed with black ink are put on racks to dry and the UV ink coated boards are kept under a powerful UV lamp for a minute or so. In many large factories, the boards are put on a conveyor belt and passed under a bank of these lamps. There may be other types of etch resist inks too as new products are constantly being introduced to the market. It is best to avoid the use of fluorescent lamps in the work area where UV printing is carried out. Fig. 23.1 shows a board with a pattern of tracks printed using etch resist ink.

The cheapest and most common etching fluid is ferric chloride. It is prepared by dissolving 500 grammes of the hydrated crystals in one liter of water. Ferric chloride solution is a toxic and highly corrosive yellowish-brown liquid. It is a nasty substance and should never be introduced into the domestic environment. Though most iron compounds are not regarded as hazardous materials, $FeCl_3$ is a notable exception. The solution can cause skin burns and the vapors can be irritating to the mucous membranes. Eye contact can be dangerous. It will stain everything it encounters such as walls, furniture, carpets, curtains, clothes as well as human skin. A separate area must be set aside for etching operations if you are planning to use the chemical for this purpose. It can etch all metals and alloys including stainless steel. The etching fluid must only be stored in a glass or plastic container.

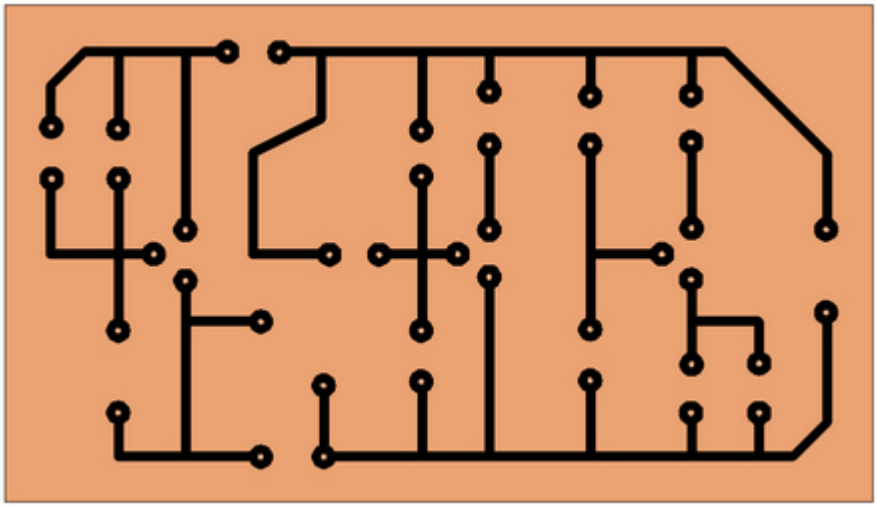

Fig. 23.1 The pattern of tracks is printed with etch resist ink on the copper facing.

Ammonium persulphate or sodium persulphate are preferred by many for etching printed circuit boards as these chemicals etch copper very effectively. They are available in a fine crystalline form that may be dissolved in water in the ratio of 250g to a liter to yield an etching fluid of the correct strength. These salts do not work very well with other metals and are quite ineffective against stainless steel. Ammonium and sodium persulphate are much more expensive than ferric chloride but are safer to work with. They yield clear solutions that enable you to monitor the progress of the work easily unlike the ferric chloride etchant, which can turn murky after a while. Persulphate etchants do possess a disadvantage in that they must be warmed a little to speed up the work. A solution maintained at a temperature of 50 to 60° C etches faster than one at room temperature. The most convenient way to heat the etching bath to this temperature without any risk of overheating is to use an aquarium heater, available from pet shops. Handle it with care, as it is made of glass. With all etching solutions, a considerable amount of acid spray and fumes are evolved, requiring the installation of efficient fume extraction equipment and provision of proper ventilation in the etching area. The workpieces must be put in the etching bath and removed from it with the aid of tongs. Protective gear and clothing should be worn by the workers.

As for the etching operation itself, this cannot be treated as a simple exercise involving nothing more than dunking the board in just any position for a specified period in the etching fluid. To achieve clean and sharp results, the board must be hung or supported in the correct position and the etching fluid agitated gently so that it may erode the metal layer with a steady action. The liquid should move constantly across the surface to be etched without remaining still. The best way to do this is to place the boards inside a rectangular plastic tray, immersed in etching fluid to a depth of half an inch. The tray is then placed on a rocking apparatus. This simple device is specially constructed to facilitate the etching operation and appears as shown in the illustration. It comprises a wooden support for the tray, hinged at one end while the other end rests on a wooden disc mounted on a shaft with its centre slightly offset from the shaft's axis of rotation. The eccentric disc acts as a cam, imparting a rocking action to the wooden board by raising and lowering it as it rotates. The angle of tilt need not be more than 10° above and below the horizontal. The speed of the cam can be anything between 6 and 12 rpm.

It is difficult to find electric motors that run at low speed, but it may be possible to find one in an electrical or hobby shop. An old table fan motor with speed control could also be

converted to serve the purpose. In either instance a small pulley on the motor should be coupled by means of a belt to a larger pulley of the same profile mounted onto the end of the shaft to provide a convenient means of speed reduction. The motor, speed control and switch should be positioned so that the etching fluid cannot splash onto them accidentally.

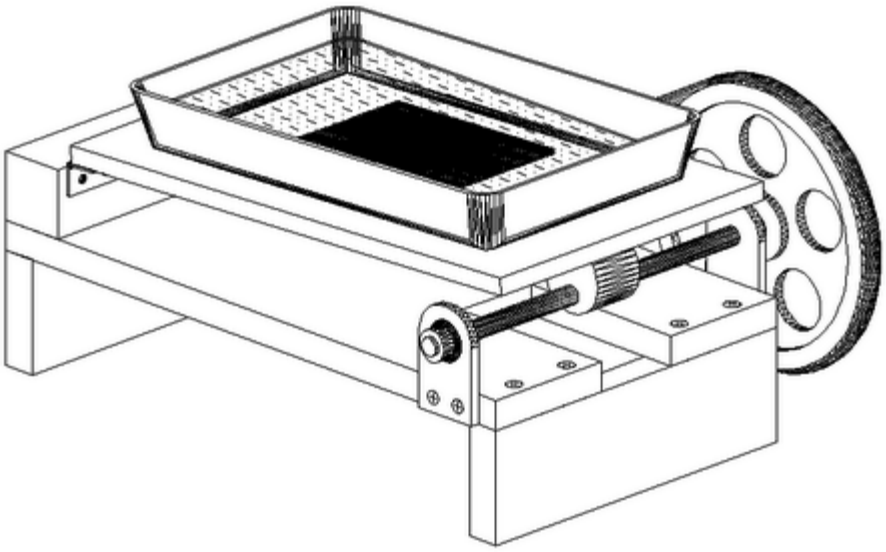

Fig. 23.2 The motorized rocking apparatus keeps the etching fluid constantly moving against the surfaces to be etched. The motor is hidden in this view.

If the printed circuit boards are kept immersed in the etching fluid for too long, undercutting may occur. This is undesirable and should be avoided. When etching is complete, the boards must be removed with tongs, washed in running water and inspected closely for any defects. If the defects can be rectified it is well and good, if not,

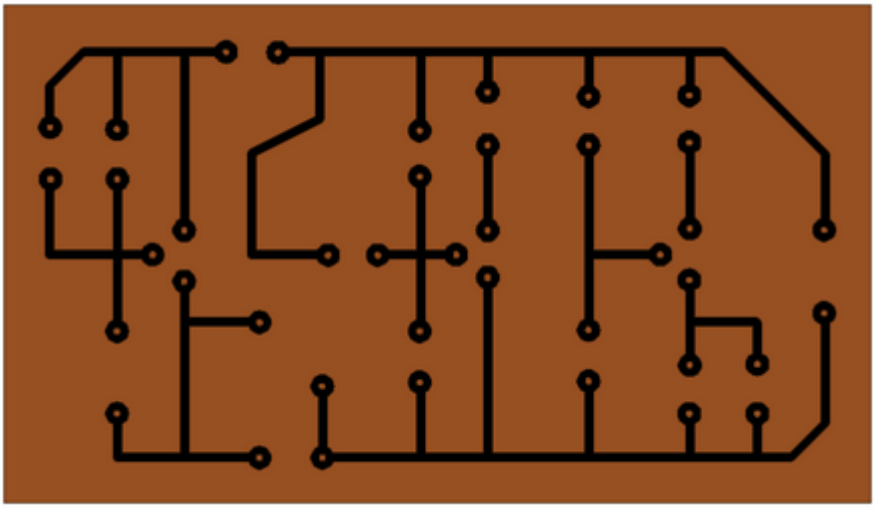

Fig. 23.3 Etching removes the copper from the unprotected areas, leaving the underlying glass/epoxy board exposed.

suitable remedial action must be taken to prevent any recurrence of the problem. The etch resist ink will still be in place, so it must be removed before the board can be put to use. The black ink can be taken off with xylene or a xylene-based solvent, while keeping in mind that xylene vapor is toxic. The blue UV ink may be removed by immersing in 5% sodium hydroxide, i.e., caustic soda solution for about half a minute and then washing it off in running water. Fig. 23.3 shows the board after etching is over and Fig. 23.4 shows the board with the resist ink cleaned off to expose the copper traces.

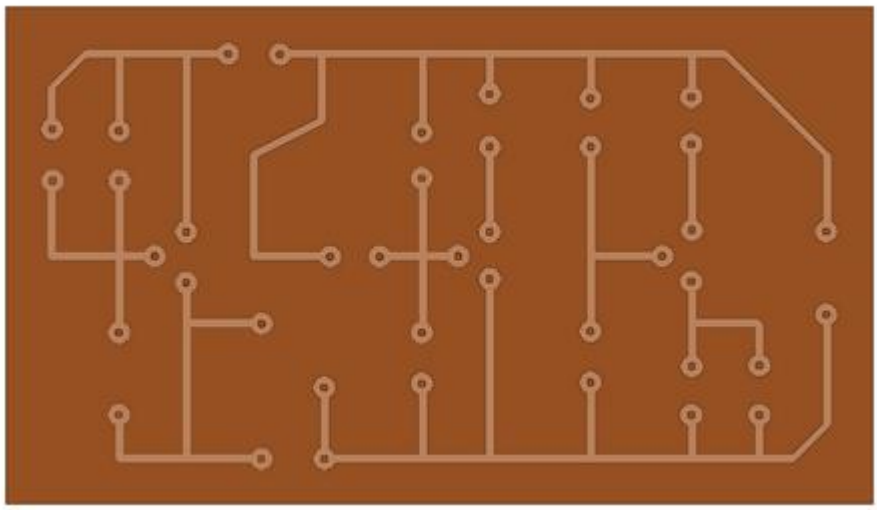

Fig. 23.4 The pattern of copper tracks will stand out clearly once the etch resist ink is cleaned off.

Sometimes screen printers may be asked to perform additional printing operations on the PCBs after the etching stage. This may involve the deposition of what is known as solder mask or solder resist. This is usually a green colored lacquer like coating that may be based on epoxy or some polymer material. The purpose of this coating is to cover and protect all parts of the exposed copper traces except the pad areas where solder will be deposited. Solder mask is a tough coating that is resistant to heat, chemicals and solvents, besides being an excellent insulator. It protects the copper from oxidation and prevents electrical short-circuiting caused by stray solder or metal particles that may accidentally bridge the gaps between traces. It is mixed with a catalyst just before application. A separate screen will have to be made for this purpose according to the drawings of the customer. When the coating has dried, it must be cured in an oven or infra-red dryer for 20~30 minutes at 150° C to develop its properties fully. The temperature and curing time may vary with different products. A matching thinner may be used to dilute the solder mask ink and wash out the screen, squeegee etc. soon after the work is over, as this type of ink should never be allowed to dry on the screen.

A further operation on the circuit board may be requested by the customer, this one involving the printing of legends used as a guide to the placement of components during assembly. In the case of single sided boards, this is printed on the reverse side as the components are mounted and the leads inserted from here. The soldering is done on the side carrying the copper layer. Other information such as brand name, logo and part number may also be added for identification. These marks are usually printed in white with some tough ink such as a two-part epoxy based type, followed by heat curing. The drilling of mounting holes at the four corners and the connection holes for the components are usually carried out by the customer but on occasion the screen printer may be requested to perform this work too.

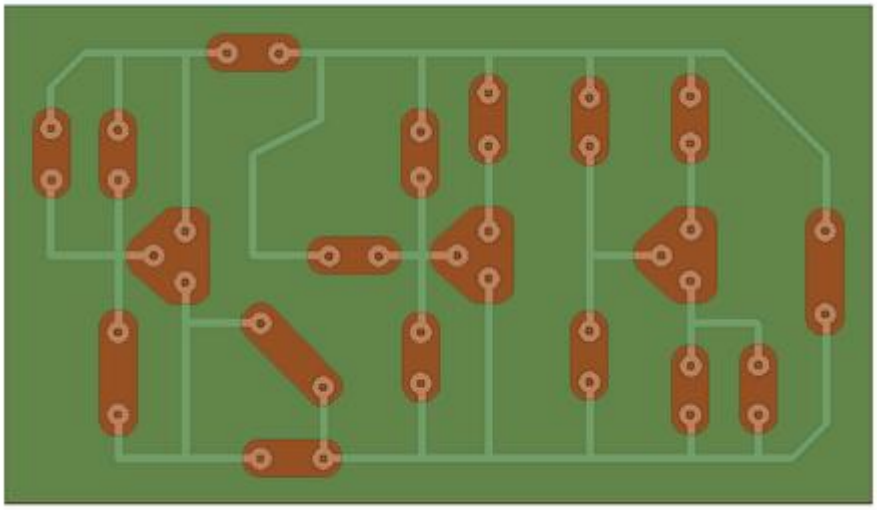

Fig. 23.5 Solder resist coating is applied on all exposed parts of the board for protection, leaving the circuit connection pads uncovered.

It must be stressed that screen printing of PCB material for etching purposes serves best for single sided boards of low and medium track density. The production of double-sided boards calls for more advanced production techniques. This is because the traces on both sides would need to be perfectly aligned with respect to each other and plated through holes provided to connect the components on both sides electrically.

The production of labels, badges and nameplates is another area in which etching techniques are successfully employed. These items can be etched after covering the areas to be protected with resist ink. The line art design may be drawn on white paper with black ink and digitized by scanning or capturing with a digital camera. Alternatively, the design may be created on the computer itself with some graphics software. A positive carrying the design is printed first and this is used to make a screen. The part to be etched could be the design itself or alternatively the surrounding area to obtain a relief effect. The metal blanks are printed with the etch resist ink through this screen. Depending on the size of the workpiece, it is usually feasible to fit in several under one screen and print them all in one pass, thereby speeding up production. To put this into practice it will be necessary to make and use a flat board with suitably shaped recesses to hold the workpieces in the correct position. This removable board is attached to the printing table whenever metal labels are to be processed.

In the case of workpieces like these, it will be necessary to cover the rear surfaces and the edges too with etch resist ink. This can be done by hand with a paintbrush. Labels, badges, and nameplates are mostly made of aluminium or brass and occasionally out of stainless steel. The most common etching medium employed with these materials despite its harsh qualities is ferric chloride as it is highly effective and cheap at the same time. The etching depths may vary widely in the case of these products and as they increase so does the likelihood of undercutting. Constant agitation minimizes the tendency to undercut so it is important to ensure steady movement of the etching fluid just as in the case of PCBs. Therefore, the rocking apparatus must be employed for this operation too. The progress of the work must be monitored closely, and the articles removed when the correct depth of etch is attained. After washing and drying, the raised areas may be buffed with a polishing wheel to give the product a good finish.

Fig. 23.6 Metal labels can be made with the lettering/ image recessed or in relief, depending on where the etch resist is applied.

Purpose built etching machines work by spraying the surfaces of articles to be etched with etchants. The corrosive mist generated by the spray should be contained inside a hood or covered enclosure as it can cause all metal objects in the vicinity to corrode rapidly.

Very often, the customer may specify that the sunken areas be covered with some colored material such as regular gloss paint, two-part epoxy ink or synthetic enamel paint. As the freshly etched and washed surfaces would be in a clean state, good adhesion of the colored medium will be assured. Some of these materials may have to be heat cured in an oven at a low temperature. If vitreous enameling is to be performed, this would call for the special equipment described in the previous chapter. Copper and brass may be vitreous enameled but not other metals. This type of enamel must be fired at a red heat in a kiln to fuse it onto the metal surface where it will form a durable glass coating.

As printed circuit boards are precision components, original etch resist ink must be used to print the pattern to meet the product specifications. For less critical work, such as that involving the production of labels, badges, etc., it may be possible to make use of standard PVC or synthetic inks instead of the expensive etch resist ink. The resistance of these inks to different etchants may vary according to the type and brand and therefore a little testing will be necessary to obtain reliable results. At the end of the etching operation, it may be more difficult to strip off these inks from the substrate too. Use various thinners first, from mild to strong before trying out other solvents. In some cases, heat may be applied successfully to break down the ink. It is easier to strip off paint from aluminium and stainless steel than from brass and iron.

Chapter 24 – General Advice

People do screen printing as a hobby or pastime but there are many who treat it as a serious, income generating business activity. Irrespective of a person's objectives in taking up screen printing, there is no doubt at all that it can prove to be an intellectually stimulating, emotionally satisfying and if done on a commercial footing, a financially rewarding activity. It is also something that can be undertaken by an average person with limited resources at his disposal. It is quite easy to learn, and one does not need to have an MBA degree to run a successful screen-printing operation. The reason that many people find screen printing so interesting is because it offers a lot of scope for giving expression to their creative talents. It also provides them with ample opportunities to produce much in the way of tangible output to showcase their expertise. When they turn out something perfect or esthetically pleasing, they can feel truly gratified and be imbued with a sense of accomplishment. A screen printer will also never have a dull moment because the nature of the activity is like that – full of surprises, of both kinds!

Considered as a purely business undertaking, it has its pros and cons just like any other. Its greatest advantage is that its startup costs can be very low when compared to most other types of businesses. A screen-printing shop can be run as a viable business concern with just the owner and three or four employees. It is a field with enormous scope and potential, able to cater to the needs of a diverse customer base. The hobbyist may use a spare room or garage at his home to do a little bit of screen printing for the fun of it and to while away his time. It is not practical though to run a commercial screen printing operation from the home for a couple of reasons. One reason is that it can take up a large amount of floor area due to the nature of the work. The other reason is that it can be a rather hazardous activity in so many ways.

Let us first consider the issue of floor area. A well-organized screen-printing shop would be divided into pre-production, production, post-production, and office areas, respectively. The pre-production unit would be responsible for the artwork, computer operations, mesh stretching, production of stencils by coating screens and exposing them, washing out, reclaiming, testing etc. The production unit is the place where the actual printing takes place together with all other activities directly associated with production such as ink mixing, print setup, ink curing and drying, washing and cleanup. The post-production unit would be concerned with counting, packing, storing, delivering, etc. The office must deal with seeking orders, purchasing, accounting, billing, collecting payments, customer relations and administration. Naturally, it requires appreciable floor area to separate these activities neatly to ensure efficient production and smooth functioning of the organization.

The work area within each unit, in particular the pre-production and production areas, should be set up ergonomically with the work benches and printing tables set at comfortable heights and with a choice of lighting sources to suit the special needs of the different activities involved in screen printing. It is also necessary to set up the layout of the pre-production department for working with screens. For stretching mesh, for holding the screen securely for coating emulsion, for drying the emulsion, for exposing screens, and so on. The pre-production section should ideally be partitioned into a well-lit zone and a subdued light zone. The latter need not be as dark as a photo lab but arranged to cut out all ultraviolet light and bright visible light when working with photosensitive emulsions and films. Windows in this section must be fitted with blinds or curtains. Low wattage bulbs of the correct color temperature must be used here.

It is also important to have a well-designed washout booth for washing screens. This should be equipped with a backlit frosted glass window set at a comfortable height, fitted with a small shelf on which the screen to be washed may be set in position and leaned

against the glass. The edges of the glass must be sealed properly with rubber beading a.k.a. weather stripping or silicone sealant to prevent water from leaking onto the other side where the lamps are mounted. The switch for this should be located at a distance away from the water spray. The booth should be equipped with a medium pressure spray head for washing out exposed stencils and a high-pressure spray head for reclaiming used screens. It may be possible to conduct both operations with a single adjustable nozzle connected to a high pressure water supply. The progress of the washout operation may be discerned clearly against the backlit frosted glass surface without having to carry the screen and hold it against a window each time. Care must be taken to ensure that water spray or mist from the booth does not get onto any electrical equipment or wiring nearby. Washout booths made of molded plastic are marketed commercially.

Powerful exposure units using metal halide lamps and electrothermal devices like drying ovens and flash dryers are high current devices and so their electrical installation and wiring must be done by a qualified electrician. Care must be exercised with heating equipment like ovens and flash dryers as they can cause burns. UV light sources are not to be treated lightly either as they can cause vision problems and skin burns. Metal halide bulbs and xenon bulbs must be switched on only when they are fully enclosed inside the exposure unit. Though it is a rare occurrence, they can explode with great violence, spewing very hot pieces of glass and metal around. It would also be most imprudent to defeat or tamper with any of the built-in safety devices on machinery and appliances though some people have done this sort of thing unwittingly on occasion.

Another key point to note is that the equipment and supplies must be arranged in a sensible and convenient manner to cut down on superfluous operator movement. Much time can be saved by avoiding unnecessary walking around. Motion study experts have established conclusively that a lot of time is wasted on factory floors by workers who have to fetch supplies and move work-in-progress around constantly. Sometimes this is unavoidable but it can be at least minimized. Time spent on planning the layout and arrangement of furniture and equipment could reap dividends later by improving the productivity of the shop.

The production area should be uncluttered and have some free space for moving around the supplies rack and drying racks mounted on castors. This area should be well lit to aid in the setting up of the screen and check the quality of the printing as it progresses. If UV inks are being used, then ordinary light bulbs or yellow fluorescent lamps may be fitted. Normal fluorescent lamps may be modified into safe lights by the simple expedient of covering them with amber or yellow cellophane or similar material. There must be a ready supply of disposable towels or rags to mop up spillages, clean the screen and wipe the hands, etc. All rags used for mopping and cleaning up should be disposed of properly and not left lying around or stuffed into confined spaces because it is a documented phenomenon for rags soaked in inks and paints containing drying oils, solvents, and other chemicals to catch fire spontaneously!

Most screen-printing inks, additives, thinners, stencil adhering liquids and screen washes contain highly volatile solvents based on organic compounds. These are collectively known as VOCs (Volatile Organic Compounds). One thing common to all VOCs is that they are highly injurious to the health of humans. Many of these possess agreeable and even pleasant odors which might lead one to believe they are innocuous substances. To ensure the safety of the operators it is essential to fit exhaust fans to get rid of the fumes and vapors generated when working with such materials. Besides being very toxic, some of these vapors can form highly explosive mixtures with air. It is dangerous to have any naked flames nearby or smoke when working with solvents or materials containing solvents. To get rid of these vapors an exhaust fan with hood should be mounted near the printing table or machine. The room should be well ventilated with good circulation of

fresh air. Workers constantly exposed to solvent vapor should wear a respirator containing activated charcoal or a similar material for chemically trapping the organic molecules. A dust mask intended for filtering particulate matter will not provide the necessary protection. As the charcoal cartridge becomes loaded with organic compounds, its efficacy drops and so it should be replaced periodically to maintain protection at an adequate level.

Not only are the vapors of solvents harmful by inhalation, but liquid solvents can also prove injurious as well, if absorbed through the skin. This can happen if you try to remove ink, paint or any other stuff from your hands by wetting them with a solvent and scrubbing. The best way to clean the hands and contaminated skin is to wipe off with absorbent tissue or towel, followed by washing with soap and warm water. Ingestion of organic solvents could prove extremely harmful or fatal. Some of these solvents are used straight like acetone, isopropyl alcohol, turpentine, methyl ethyl ketone, xylene, and toluene but most are found as ingredients in inks, thinners, additives, adhesives, stencil adhering fluids and screen wash. The current trend is to switch over to the use of water based inks wherever possible to avoid the hazards associated with solvent based products. Washing up and cleaning call for nothing more than tap water and soap or detergent. Exposure to VOCs can result in various afflictions such as headaches, dizziness, nausea, aggravation of respiratory problems, dermatitis, as well as irritation of eyes and mucous membranes. Chronic exposure could cause serious neurological problems, such as lack of coordination, loss of memory, and a decrease in intelligence, which is a risk you can hardly afford to take!

Apart from VOCs, the screen printer's cupboard may contain a whole plethora of dangerous substances such as corrosive acids, caustic alkalis, oxidizing agents, carcinogens, heavy metal compounds and various other poisons. For example, etchants are strongly acidic, mesh prep is alkaline, dichromates and mesh stripper are oxidizers. Many coloring agents contain heavy metals. Most of the remaining substances are harmful too in some way or the other. Most chemicals listed here could cause liver or kidney damage if ingested. Therefore, being hazardous materials, they should be treated and handled with the greatest care and respect. After working with these chemicals, which includes the printing operation itself, wash your hands thoroughly before partaking of any food. It is also not advisable to keep these products in the home as they can end up in the wrong places or in the wrong hands. All containers should have properly fitting lids, be lightproof if necessary and correctly labeled.

The next issue is environmental. All factory owners should have some consideration for the environment and so should think twice before disposing of hazardous materials carelessly. As expounded earlier, most of the inks and other chemicals used in this trade are highly toxic and could cause serious pollution of the groundwater if simply flushed down the drain. The best way to dispose of leftover toxic materials is to soak them up in rags and incinerate them completely, after fully drying the water-based ones. Dangerous hardware items like burnt out high wattage bulbs should be surrendered to a municipal hazardous waste depot for disposal to prevent injuries to curious children and other persons who may not be aware of the risks involved in messing around with such objects. These bulbs contain gas under pressure and can shatter explosively if dropped.

The business aspects of a screen-printing operation should also be studied with care. As this is a service sector activity, every effort should be made to meet the delivery deadlines on schedule without any lapses. This implies that occasionally you may have to burn the midnight oil or sacrifice your weekends. Quality control is another matter that should receive the greatest attention if the business is to survive and prosper. Nothing can so effectively run down a business like this than shoddy workmanship. Remember that economies of scale dictate that the larger the order, the lower will be the unit cost of

production and higher the profitability. It would be worthwhile putting in some effort to obtain standing orders for print work from a couple of large factories so that you can get business regularly without having to go out in search of new customers all the time. So, securing larger orders and establishing a regular client base can ensure a steady business turnover and profits.

One common mistake that newcomers to this field make when setting up shop is to buy inappropriately large quantities of materials and supplies based on certain unfounded assumptions. As touched upon in earlier chapters, during the actual printing and testing stage it may transpire that some of the items purchased in bulk do not ideally meet the requirements and specifications drawn up for the product. The shop owner will then need to run out and purchase additional supplies with different characteristics. This can be aggravating as time will be wasted and money spent unnecessarily. If the printer is unable to return or exchange the goods, he will then be burdened with a stock of expensive materials for which he can find no immediate use. Moreover, much of it can turn out to be supplies like ink, binder, or photosensitive stock with limited shelf life!

Desist from undertaking to print any offensive, obscene, subversive, or defamatory material as this can get you into serious trouble with the law. Do not copy trademarks or make unauthorized reproductions of copyrighted material. Though it is not illegal to do so, avoid printing any subject matter that is in bad taste. Pay attention to the local fire, health and safety regulations. There is plenty of scope and possibilities for making money in this field by engaging in honest and straight business. Therefore, there is no need at all to dabble in questionable activities that can prove detrimental to your business interests and harm your reputation at the same time.

When one embarks on this venture, unforeseen complications and unexpected problems will surely be encountered during the initial stages, but a competent printer would possess the imagination and the resourcefulness to work around those obstacles without throwing up his hands in despair. In fact, most production hurdles can usually be surmounted by putting in some extra effort and/or by adopting a different approach. Anyone launching a new project should think positively because nothing undermines morale and performance like the intrusion of negative thoughts.

The progressive entrepreneur will also constantly be on the lookout for information that will keep him abreast of the latest developments in his specialized field of activity. New materials, processes, equipment, and machinery are being introduced all the time in this industry, which continues to evolve steadily.

The persons most likely to succeed in this field are those who possess some general technical knowledge that includes a bit of chemistry and a certain level of mechanical aptitude coupled with the ability to work with simple hand tools. There are few purely mechanical procedures in screen printing, and it is necessary to employ some finesse in almost every type of operation. The most important quality required though would be a capacity for hard work, and a willingness to put in long hours. There can be no doubt that running a screen-printing operation calls for much physical exertion, unlike say, writing a book on the subject, which involves ‘merely’ intellectual effort! Finally, to become a real expert in this trade one must be willing to keep on learning, accumulate a great deal of experience and strive for perfection constantly.